Climate Change
Observed and Projected

Jim Zandlo
State Climatology Office - DNR – EcoWaters

MN Forest Resources Council Meeting
March 23, 2011

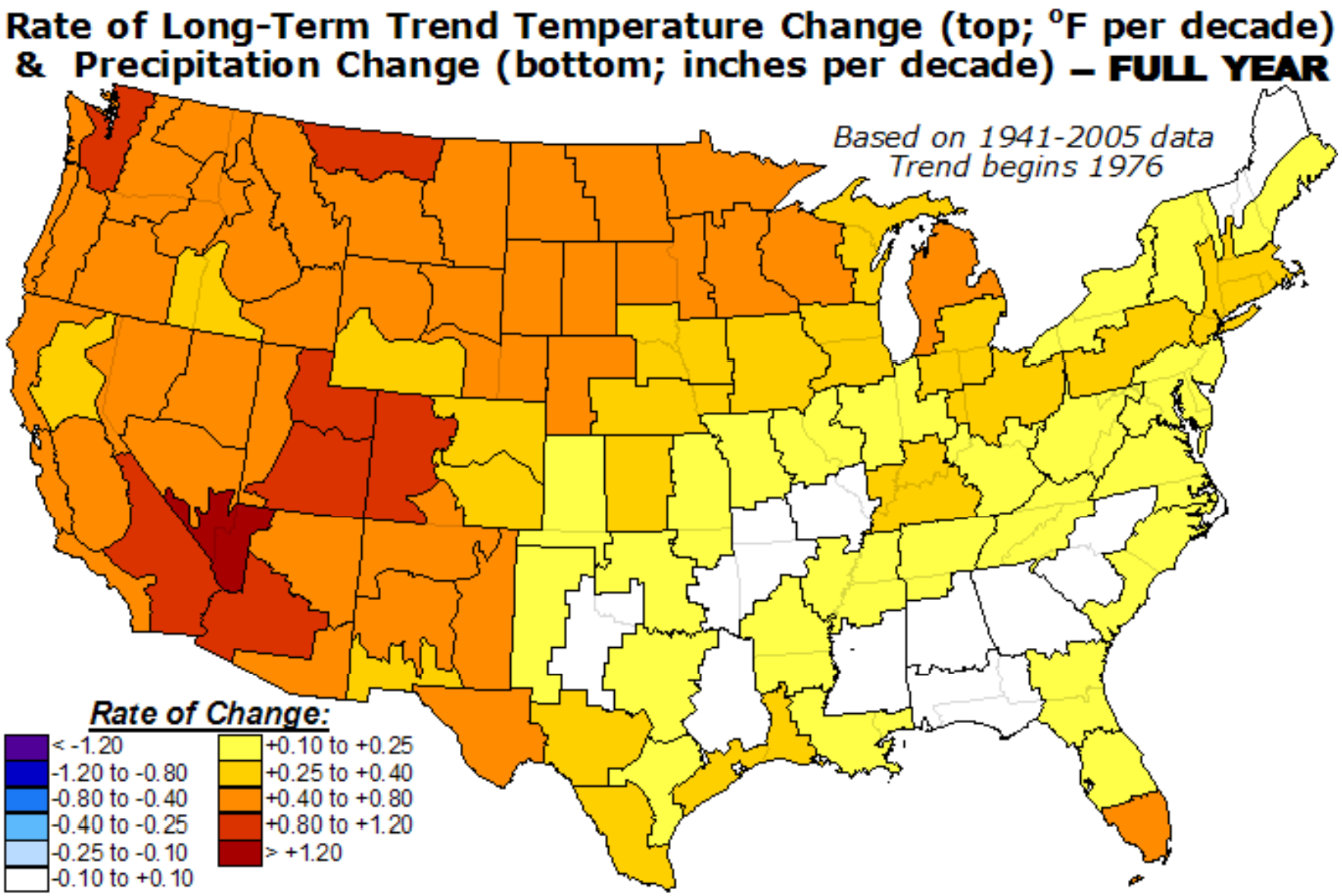
Observable Climate Changes

Rates of changes in time have generally intensified since about 1980.

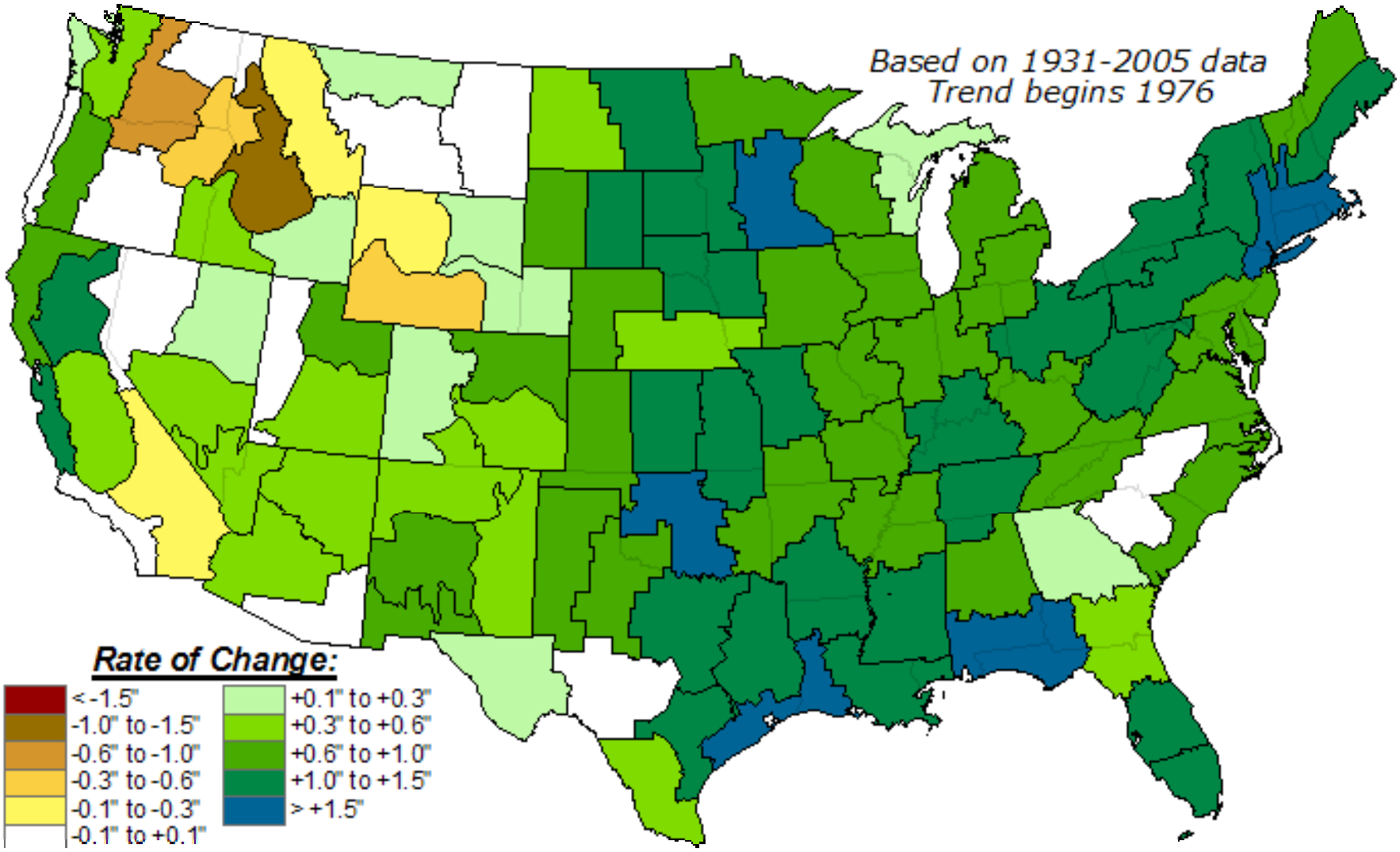
- Temperatures warming
- Precipitation increasing
  - Some precipitation conditions returning to conditions of about 100 years ago.
- Other conditions affected by changing climate
  - Lake ice dates and water temperature
  - Streamflow?
  - Other ‘natural resources’?

Caveats

- Over longer time periods not as ‘one-sided’.
- Non-climatic influences in the data

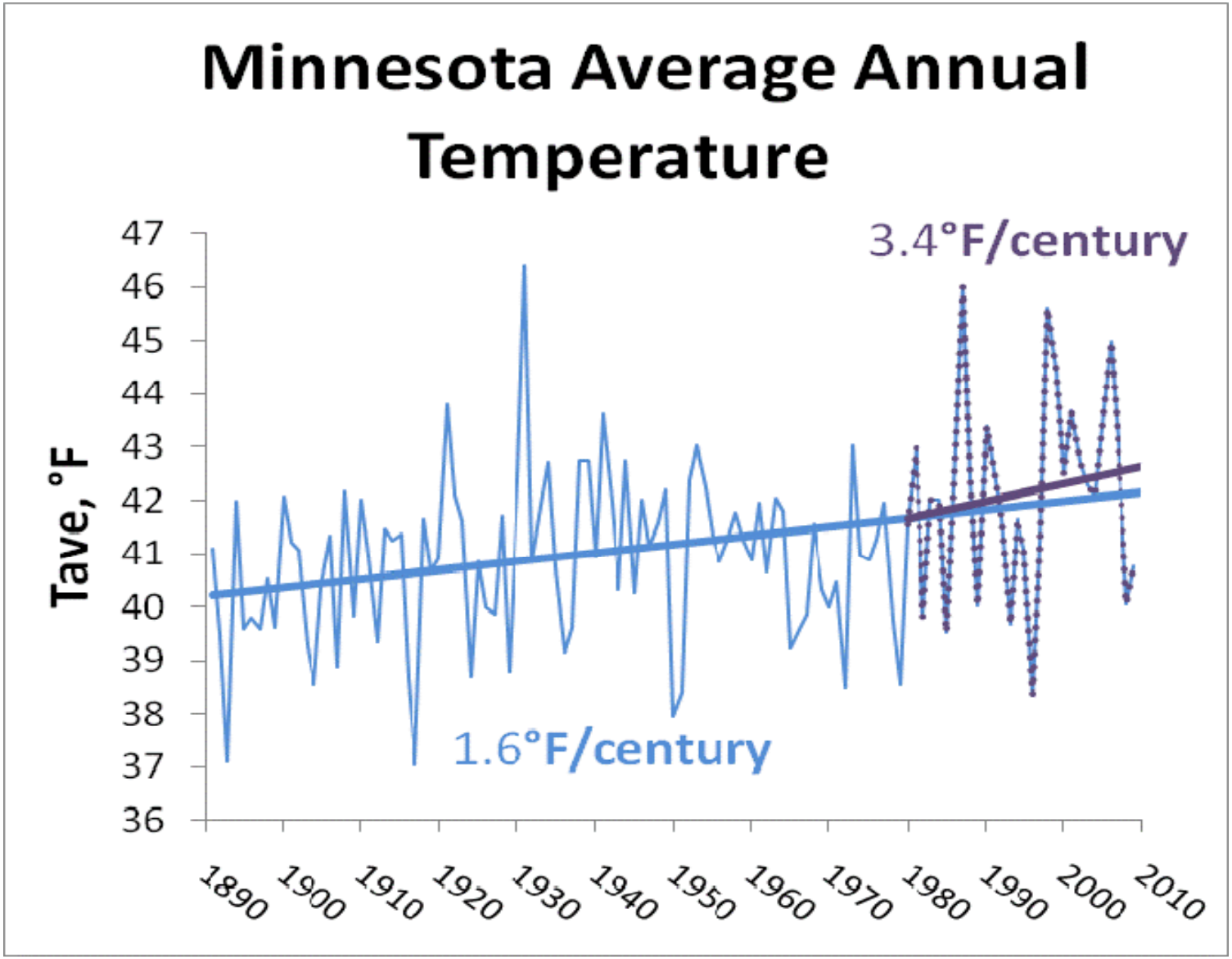


http://www.cpc.ncep.noaa.gov/anltrend.gif



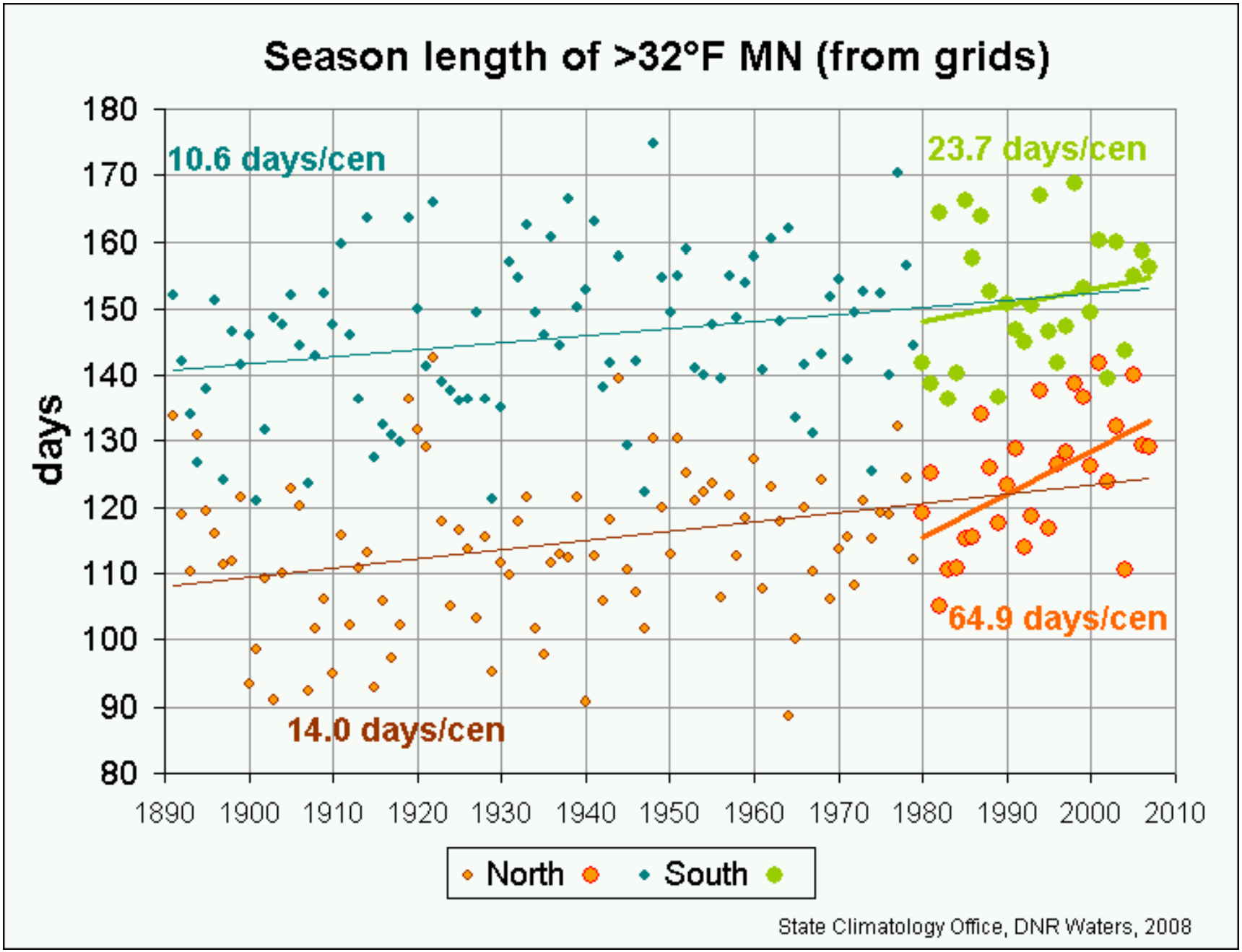
http://www.cpc.ncep.noaa.gov/anltrend.gif

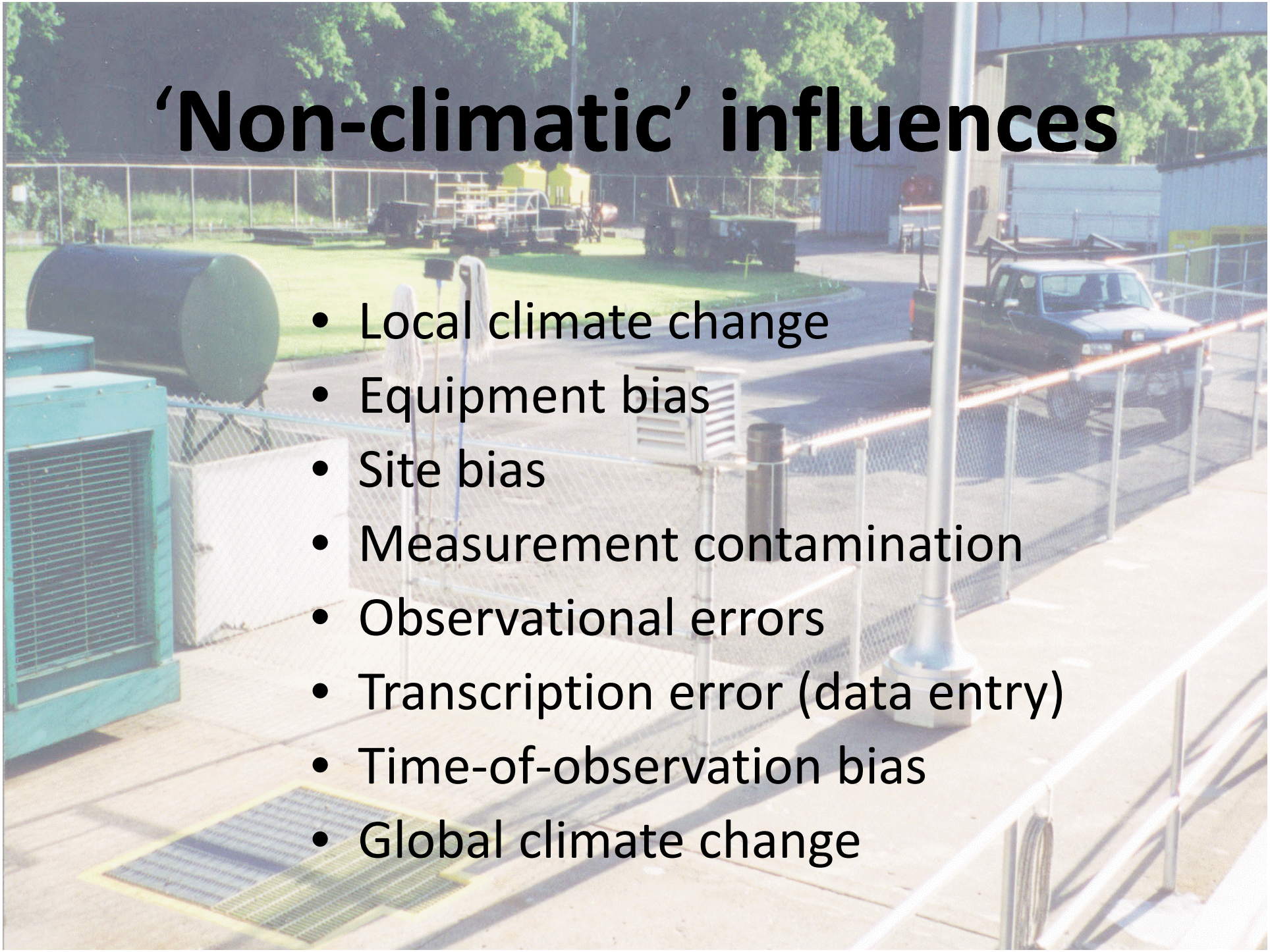
Some observed changes in the climate of Minnesota


Minnesota Average Annual Temperature
Tave, °F
47
46
45
44
43
42
41
40
39
38
37
36
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
3.4°F/century
1.6°F/century

Temperature

- Increasing everywhere
  - more in north (top 1/3 of Minnesota)
  - more rapidly recently (since 1980)
  - more at night (Tminimum)
  - more in winter (Dec-Feb)
- Maps of observed warming of the last decade show warming everywhere. Some hint of extra warming around urbanizing locations.
- Water temperature of Lake Superior warming as well.


Season length of >32°F MN (from grids)
180
170
160
150
140
130
120
110
100
90
80
days
10.6 days/cen
23.7 days/cen
64.9 days/cen
14.0 days/cen
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
North
South
State Climatology Office, DNR Waters, 2008

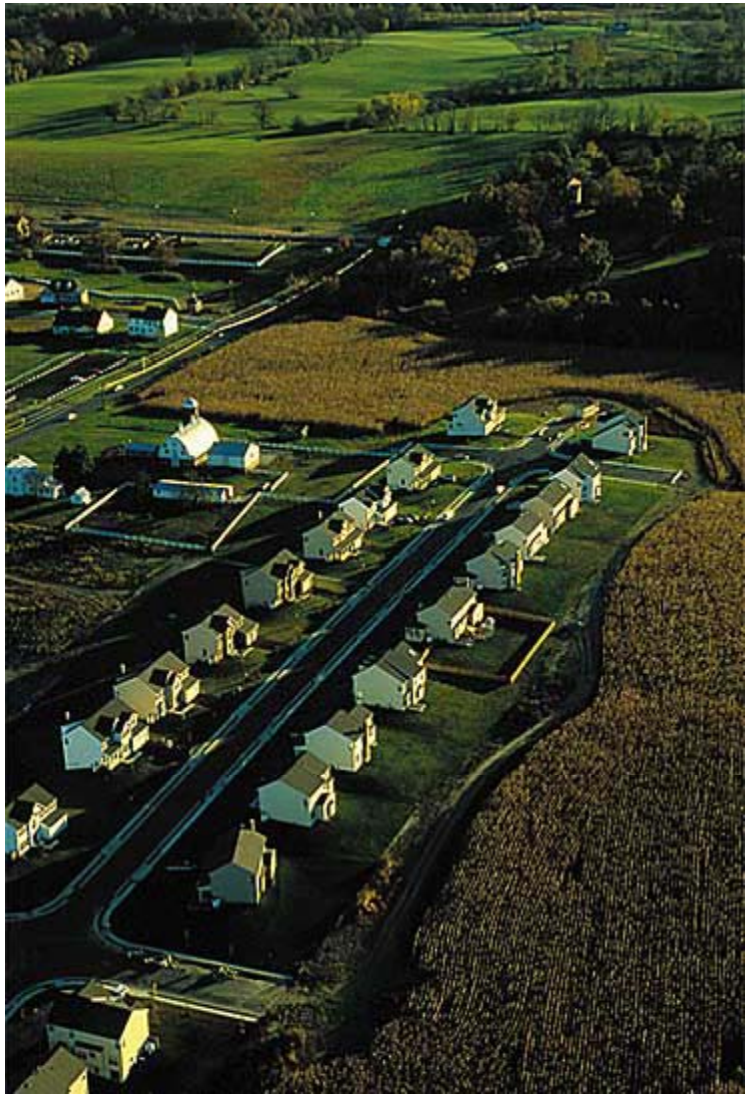


‘Non-climatic’ influences

- Local climate change
- Equipment bias
- Site bias
- Measurement contamination
- Observational errors
- Transcription error (data entry)
- Time-of-observation bias
- Global climate change

‘Non-climatic’ influences

- Local climate change
  - Land-use
    - Urbanization
    - Forest regrowth, conversion
    - Agricultural practice
      - No-till
      - Irrigation or not



http://duckwater.bu.edu/urban/sprawl.jpg

‘Non-climatic’ influences

- Site bias change
  - ‘minor’ station moves
  - 100 feet elevation, 5 miles allowed
  - ‘minor’ equipment moves ‘on-site’
  - Site exposure
    - Tree growth
    - Buildings, roads, other infrastructure added

‘Non-climatic’ influences

- Site bias change
  - ‘minor’ station moves [H1, SL]
    - 100 feet elevation, 5 miles allowed
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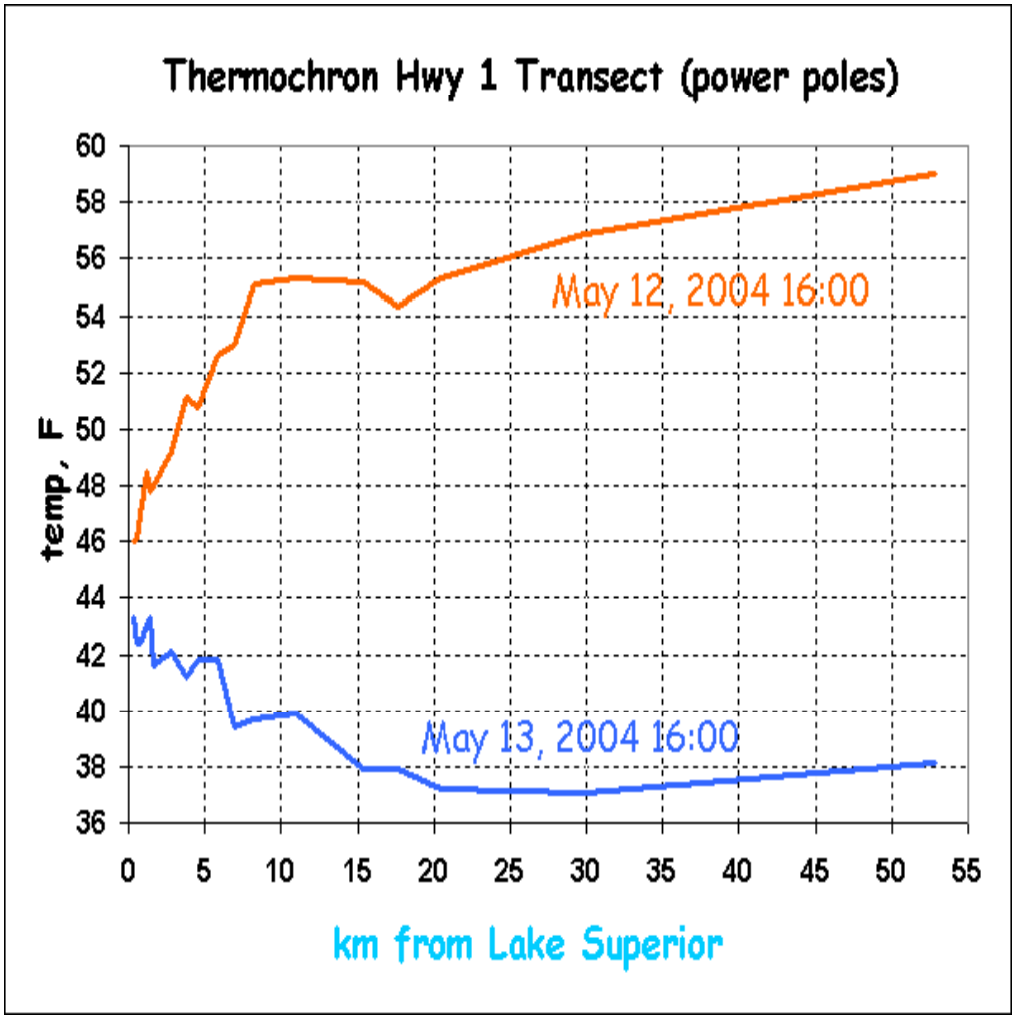
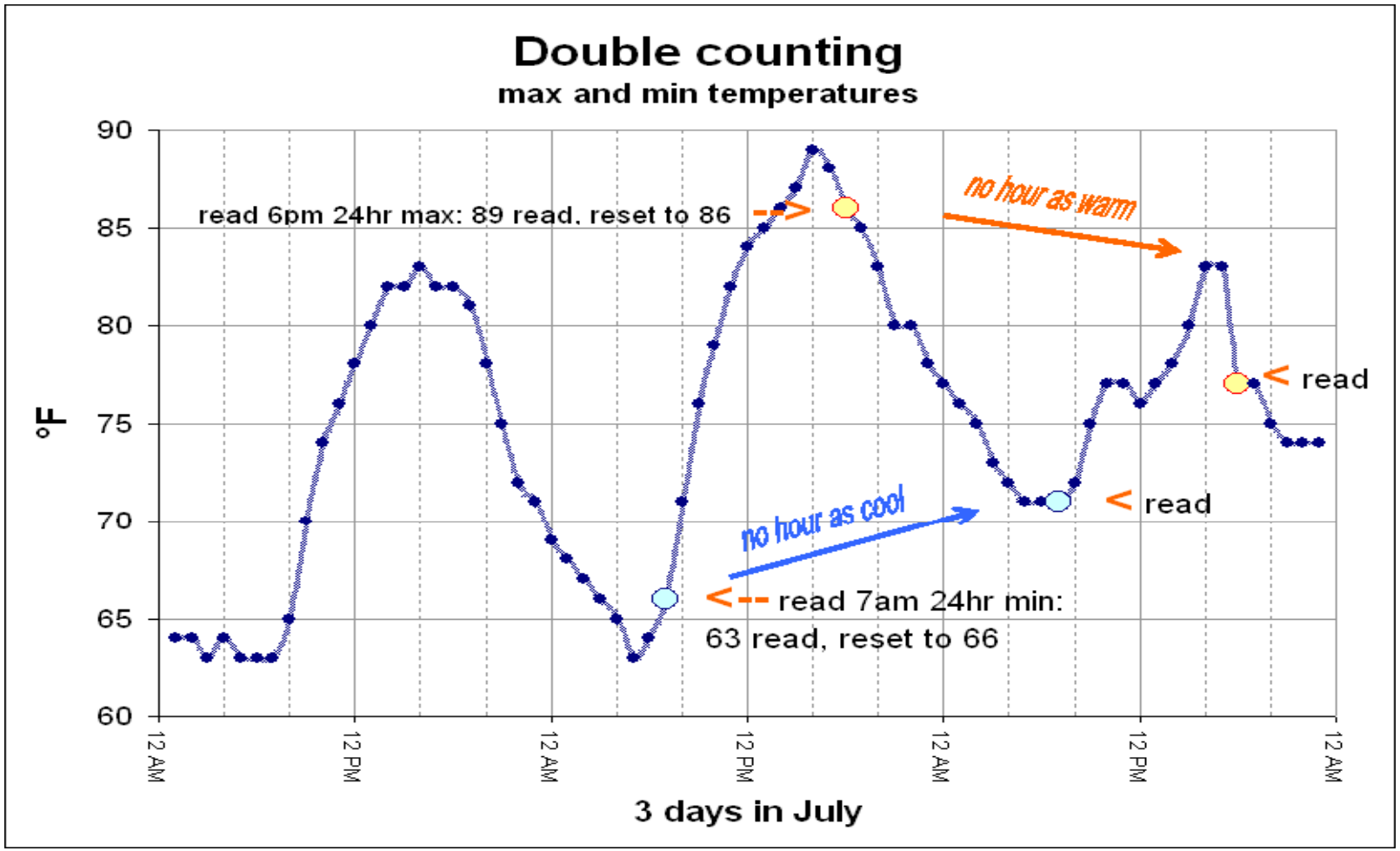
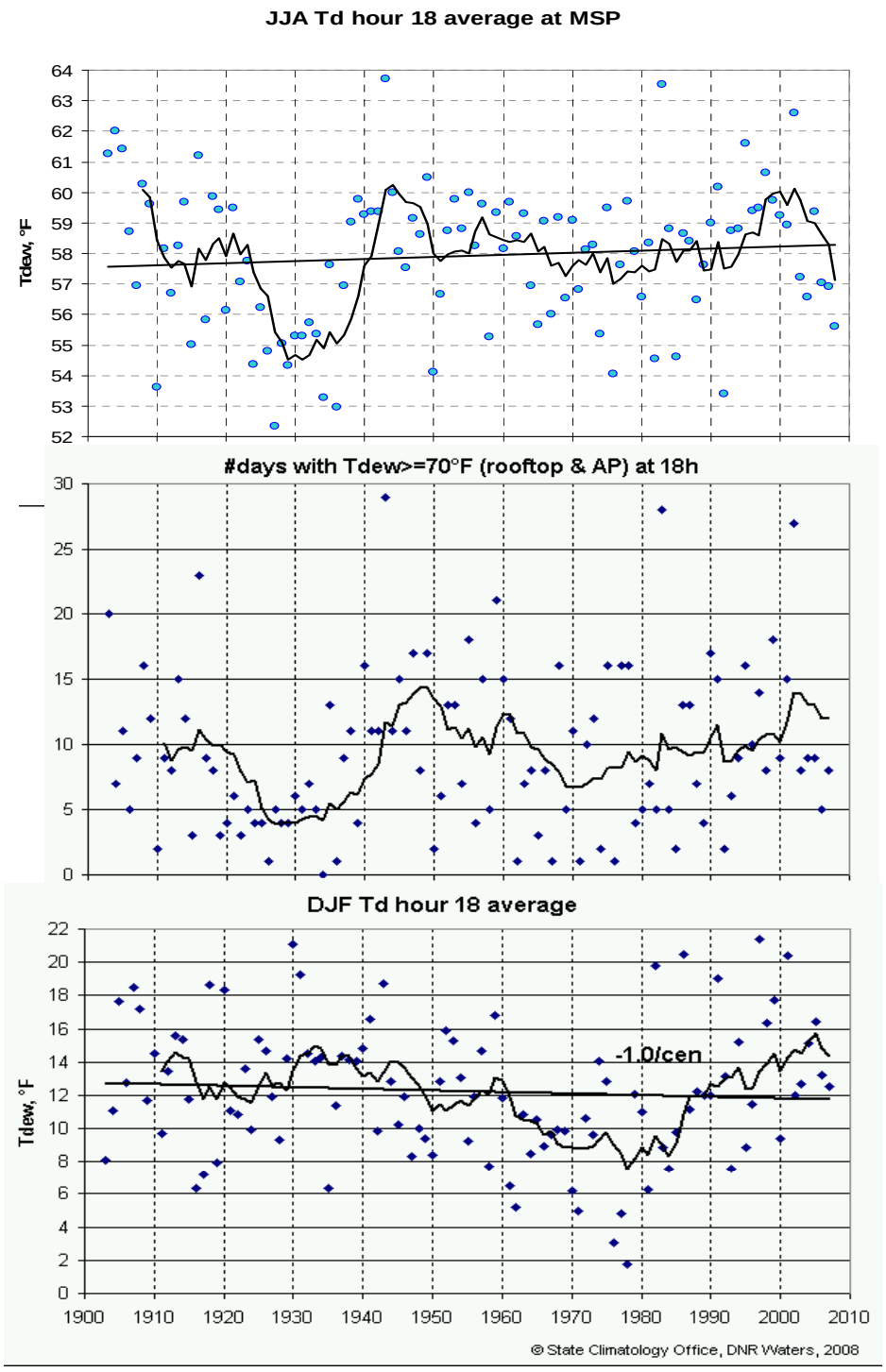


‘Non-climatic’ influences

- Time-of-observation bias



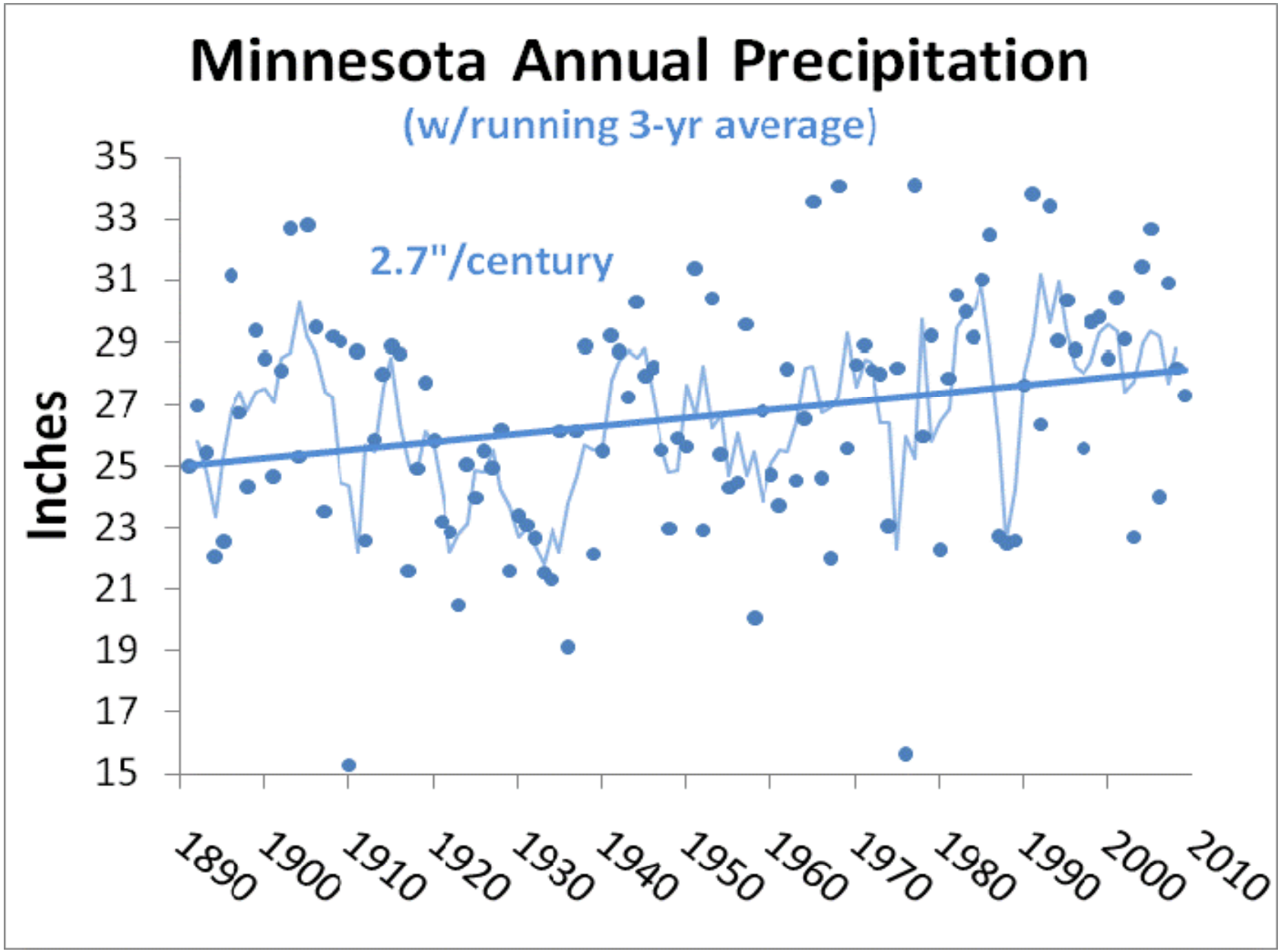


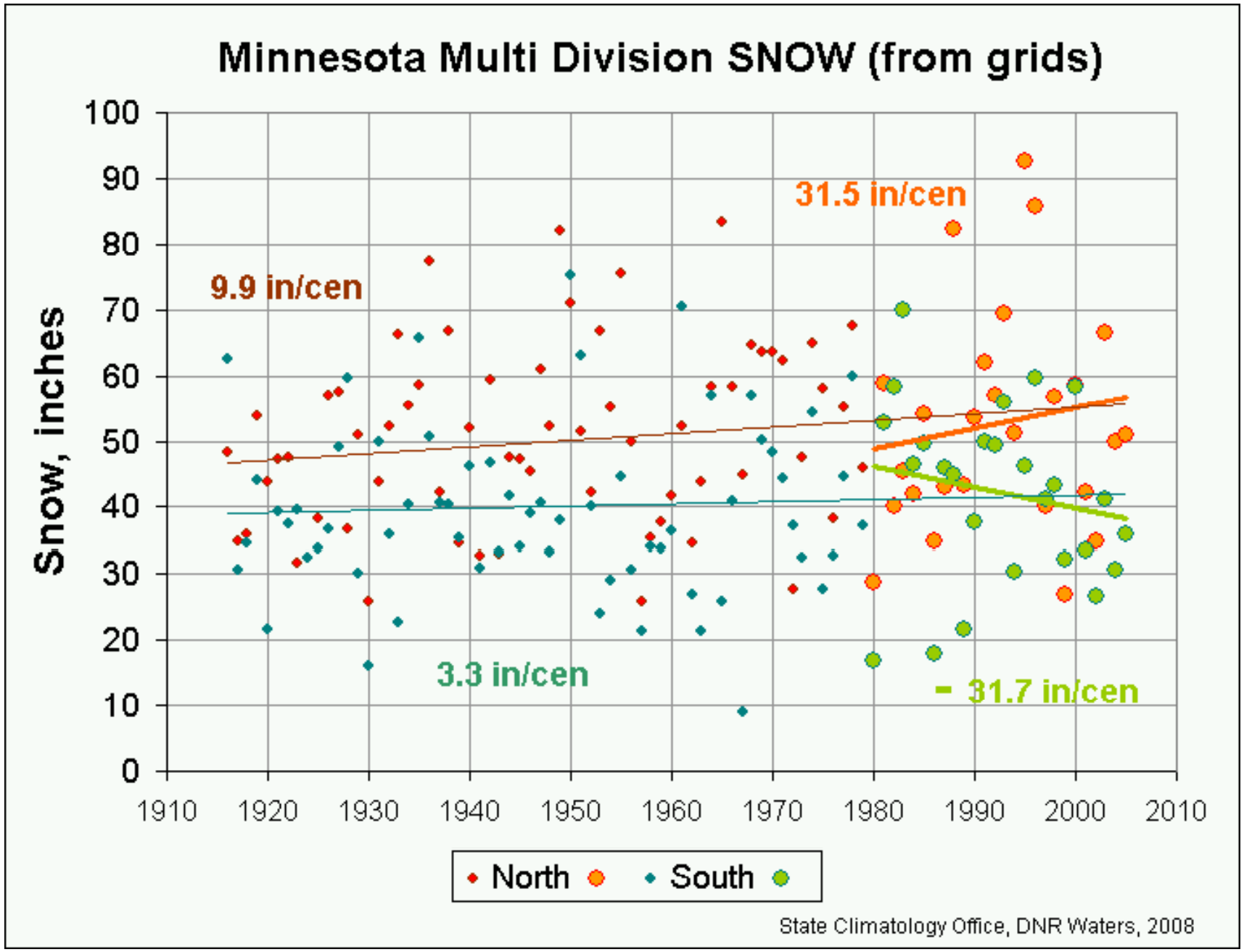
Atmospheric Humidity

- Average *dewpoint* temperature is up slightly in summer, in winter dropping until about 1980 then recent rapid rise.
- Rising temperatures impacts may be amplified by rising air heat content due to humidity.
- Number of very humid days (Tdew>70) rising rapidily in last few decades but was as high in the 1940s.
- Summer dewpoints dropping off less at night.

Precipitation, Snow, Snow Depth

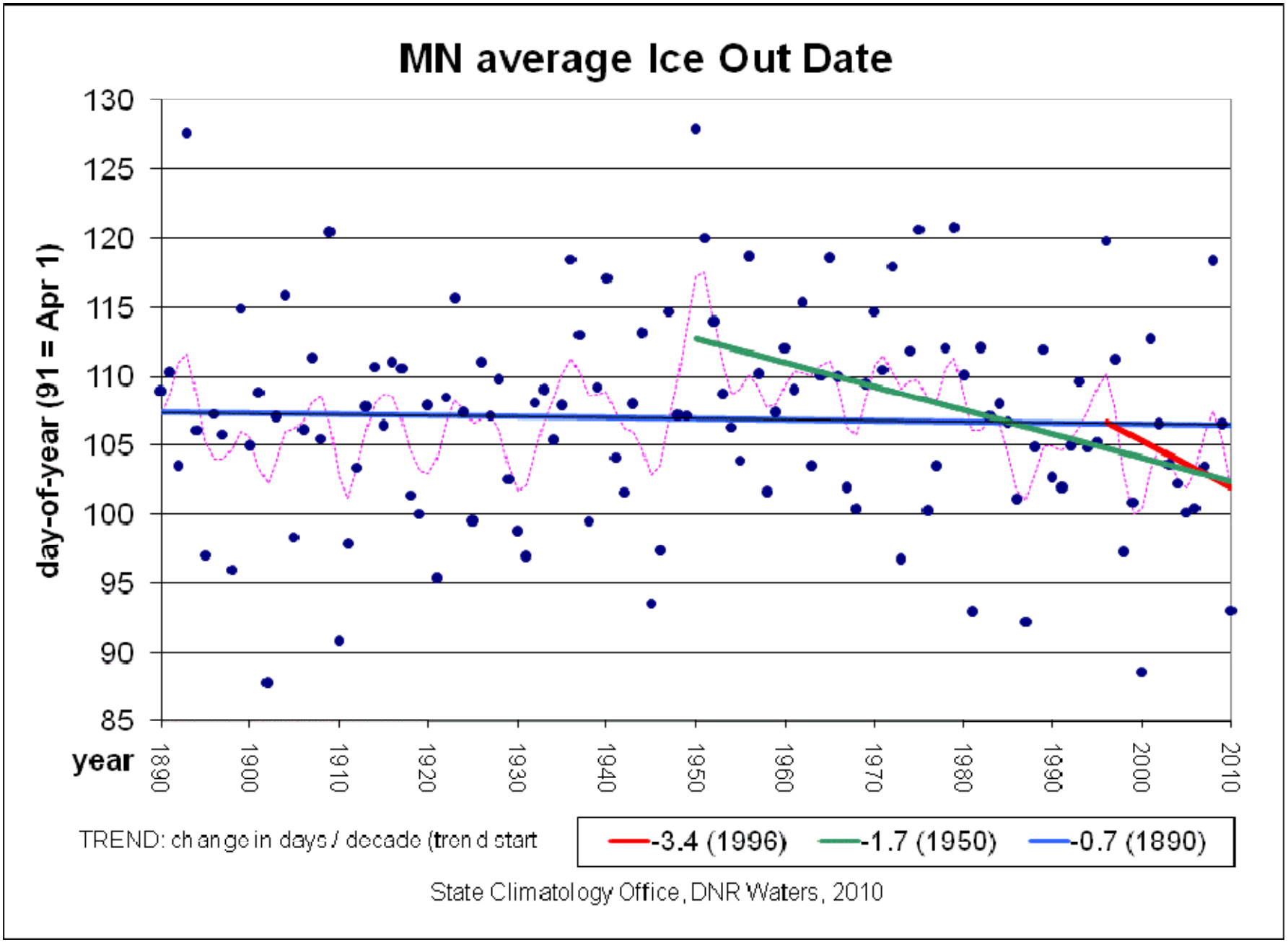
- Increasing since 1930s ‘dust bowl’ years.
  - ‘below normal’ year unusual since 1990.
- Number of heavy rain events increasing for decades but was as high a century ago.
- Snow fall generally increasing but recently decreasing in south.

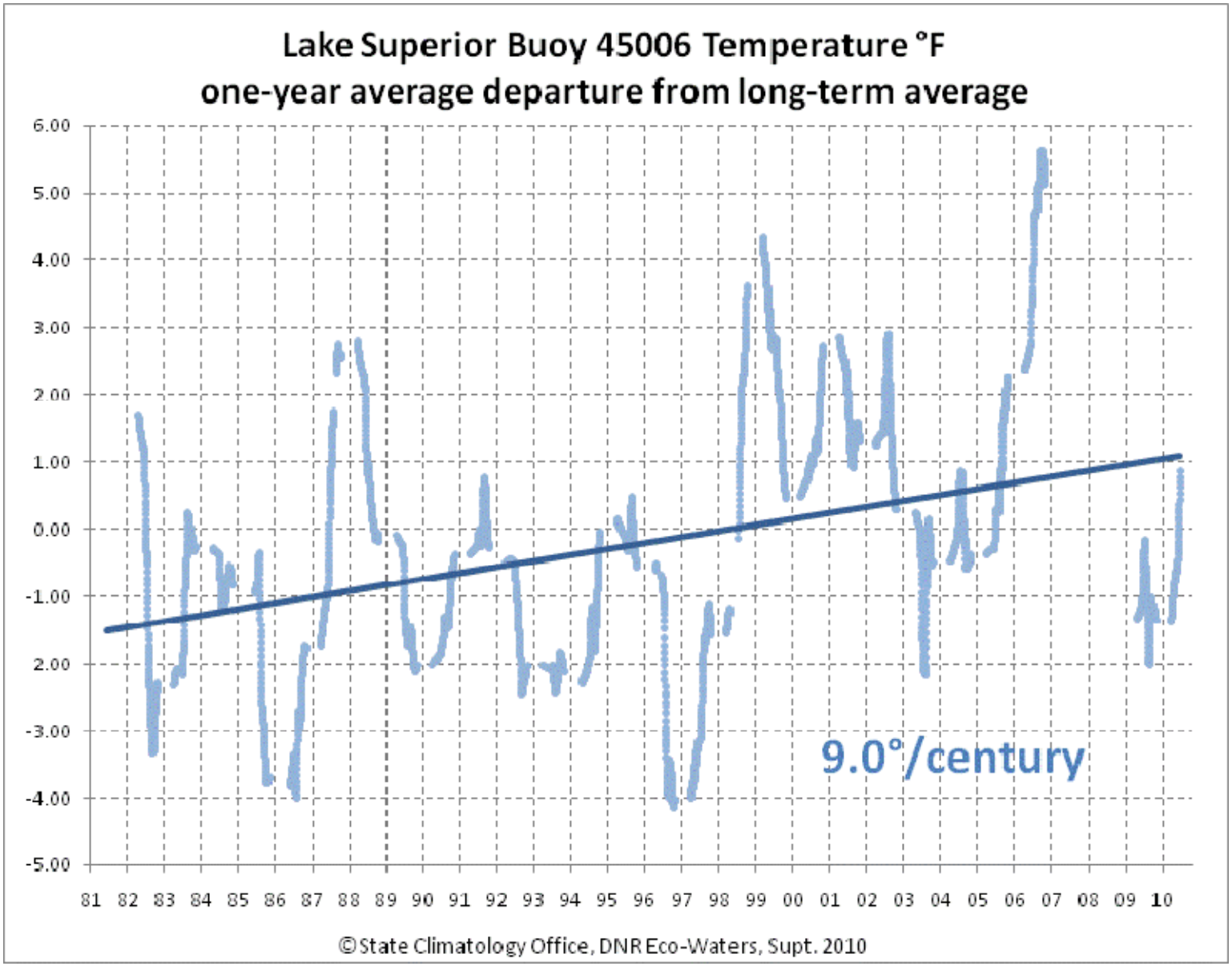

Minnesota Annual Precipitation
(w/running 3-yr average)
2.7"/century
Inches
35
33
31
29
27
25
23
21
19
17
15
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010

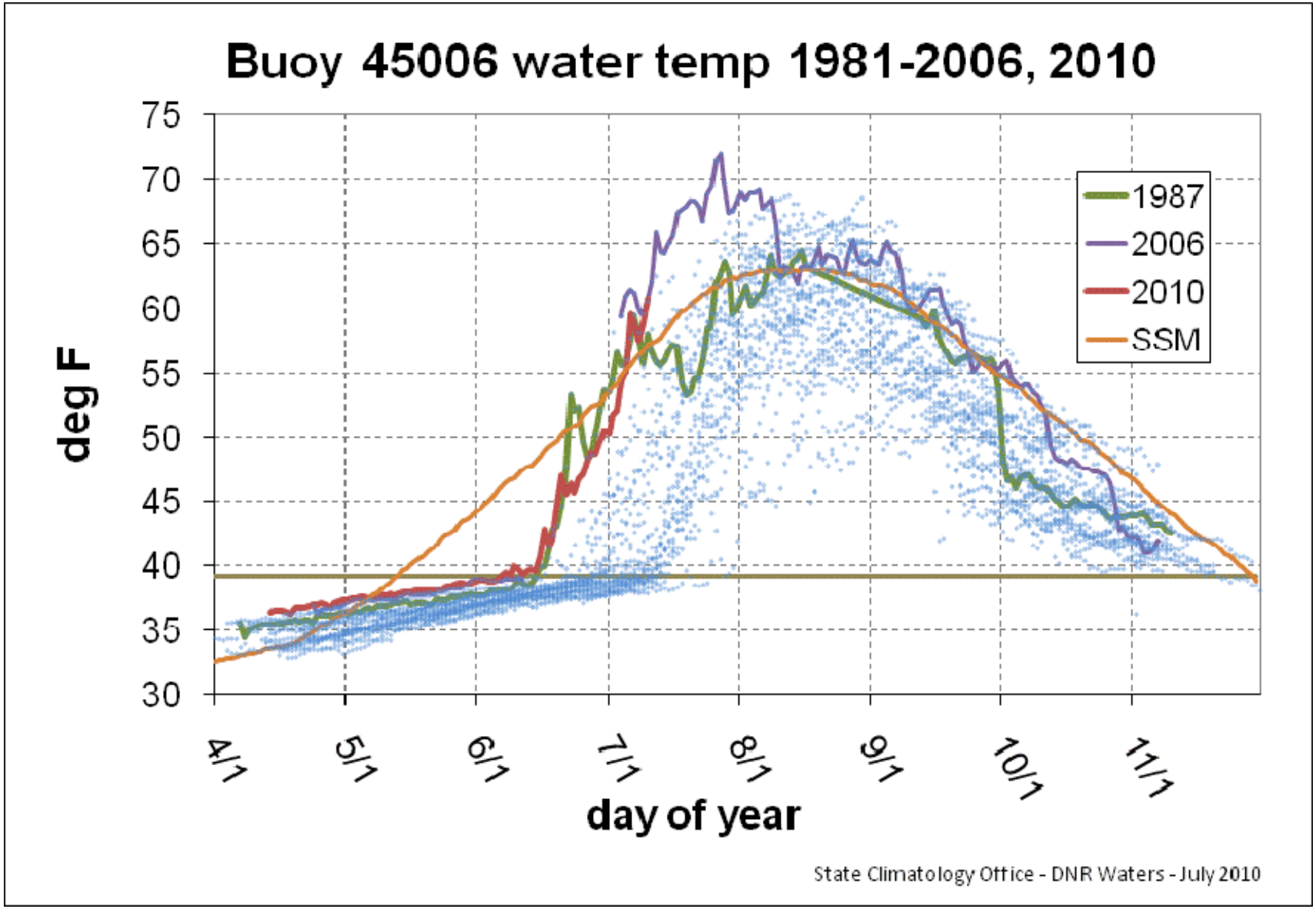

Minnesota Multi Division SNOW (from grids)
Snow, inches
100
90
80
70
60
50
40
30
20
10
0
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
9.9 in/cen
31.5 in/cen
3.3 in/cen
- 31.7 in/cen
North
South
State Climatology Office, DNR Waters, 2008

Lake Ice Out Dates

- Trend toward earlier dates has been increasing
- Pattern of ice out dates across the state is 3-4 days earlier now than it was about 35 years ago.


MN average Ice Out Date
day-of-year (91 = Apr 1)
130
125
120
115
110
105
100
95
90
85
year
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
TREND: change in days / decade (trend start
-3.4 (1996)
-1.7 (1950)
-0.7 (1890)
State Climatology Office, DNR Waters, 2010


Lake Superior Buoy 45006 Temperature °F
one-year average departure from long-term average
6.00
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
2.00
-3.00
-4.00
-5.00
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10
9.0°/century
©State Climatology Office, DNR Eco-Waters, Supt. 2010


Buoy 45006 water temp 1981-2006, 2010
deg F
75
70
65
60
55
50
45
40
35
30
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
day of year
1987
2006
2010
SSM
State Climatology Office - DNR Waters - July 2010

Some existing ‘future climate’ tools

Special Report on Emissions Scenarios (SRES) of *Fourth Assessment Report (AR4)* vs. projected global average surface warming until 2100

AR4 SRES	More **economic** focus	More **environmental** focus
Globalization (homogeneous world)	**A1** rapid economic growth (groups: A1T; A1B; A1Fl) **1.4 - 6.4 °C**	**B1** global environmental sustainability **1.1 - 2.9 °C**
Regionalization (heterogeneous world)	**A2** regionally oriented economic development **2.0 - 5.4 °C**	**B2** local environmental sustainability **1.4 - 3.8 °C**

Adopted from: http://en.wikipedia.org/wiki/Special_Report_on_Emissions_Scenarios

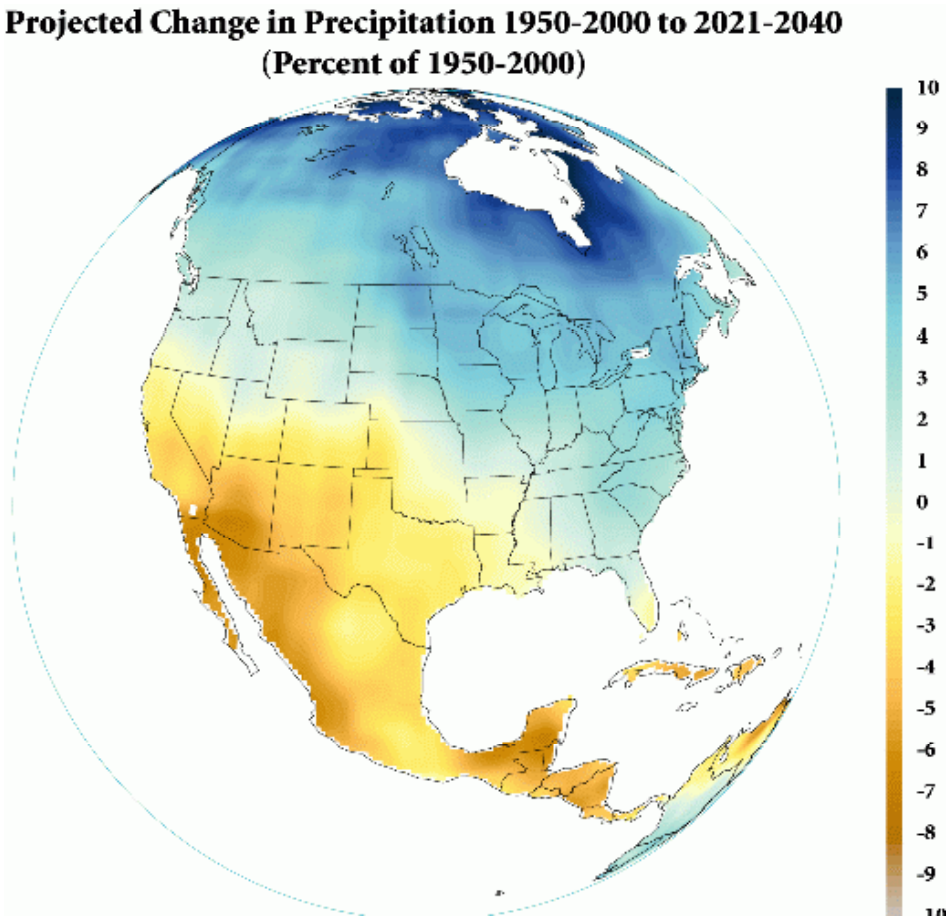
The Modeled Future

some examples of tools and 'data'

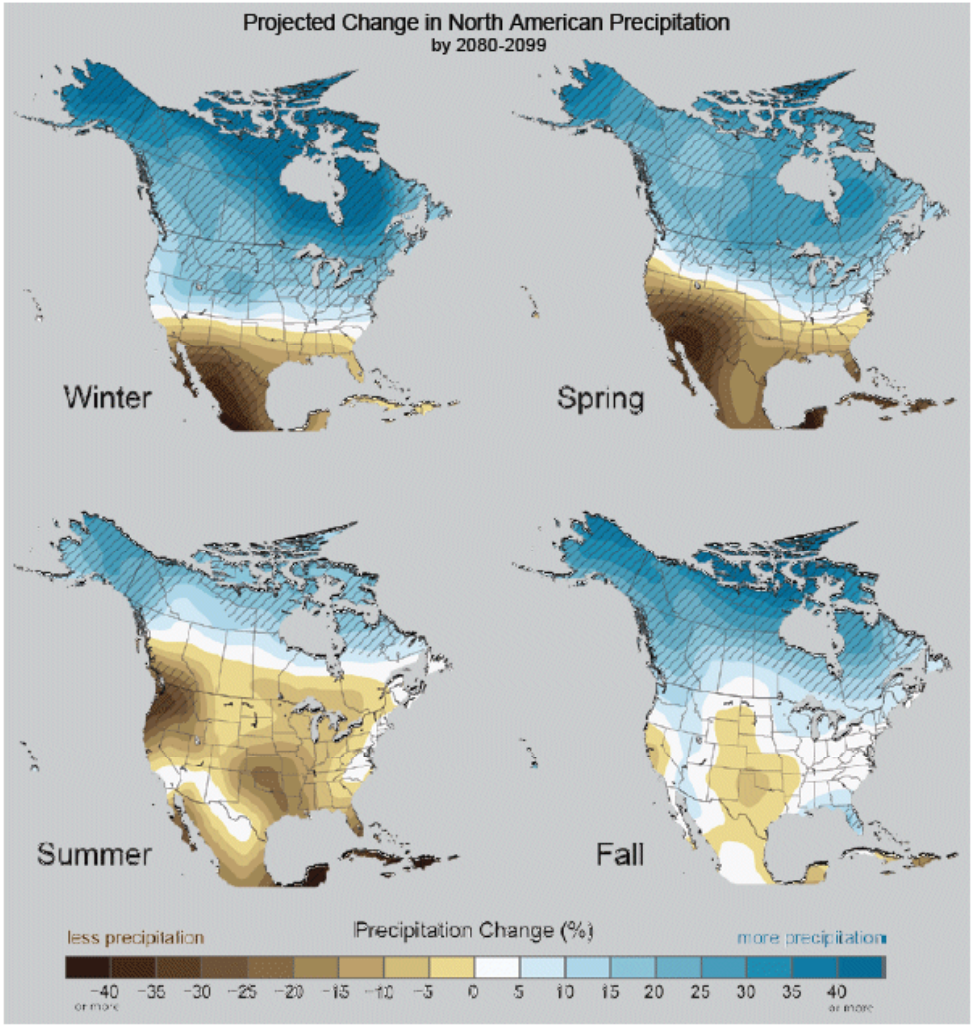
- IPCC reports http://www.ipcc.ch/
- Statistically downscaled monthly GCM *
  - The data http://gdo-dcp.ucllnl.org/
  - Summary maps; Climate Wizard http://www.climatewizard.org/
- Dynamically downscaled GCM *
  - NARCCAP http://www.narccap.ucar.edu/
- All the GCM output *
  - PCMDI (info) http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php
  - ESG (downloads) https://esg.llnl.gov:8443/index.jsp
  - Model host specific websites
- SDSM Statistical DownScaling Model https://co-public.lboro.ac.uk/cocwd/SDSM/
- Panoply netCDF viewer * http://www.giss.nasa.gov/tools/panoply/
- 'Climate Scenario at a Place' [in Minnesota] http://climate.umn.edu/mapClim2007/tsSc.asp

* All GCM, including downscaled, model time series data is distributed in netCDF format. Windows programs, s.a. Excel, don't 'know it'. A viewer or ability to write computer code is required for use. Some ESRI products may have ability to use netCDF. A single netCDF file is typically hundreds of Mb, commonly a Gb or more. There are hundreds of netCDF files available.

Pretty big picture projections …



Average of 19 climate models.
www.ldeo.columbia.edu/res/div/ocp/drought/science.shtml



Global Climate Change Impacts in the United States.
www.globalchange.gov/usimpacts

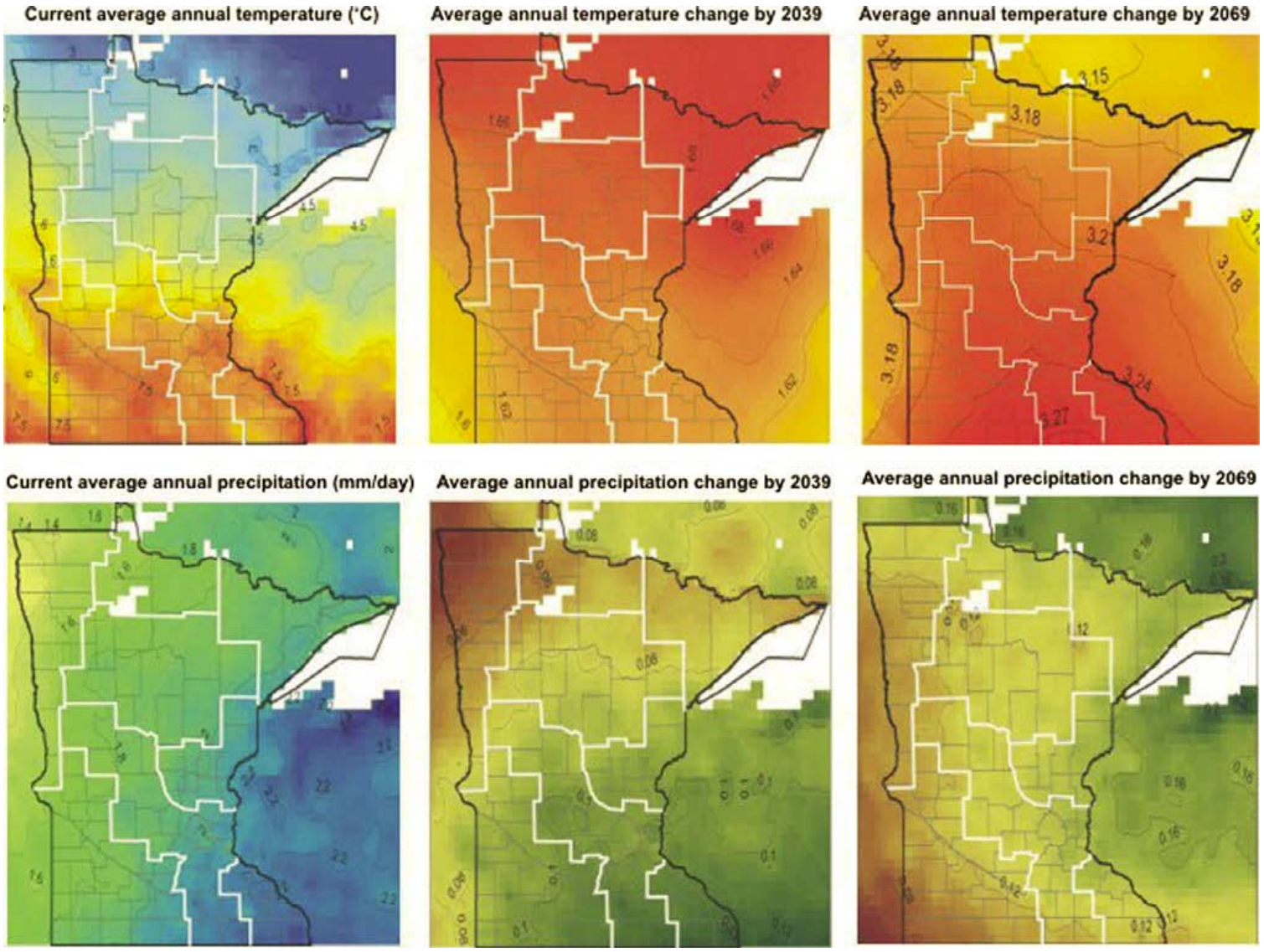
IPCC AR4 A1B projections from 21 models

		Temperature Response (°C)						Precipitation Response (%)				
Region[a]	Season	Min	25	50	75	Max	T yrs	Min	25	50	75	Max
2080 to 2099												
CNA	DJF	2.0	2.9	3.5	4.2	6.1		-18	0	5	8	14
	MAM	1.9	2.8	3.3	3.9	5.7		-17	2	7	12	17
30N,103W	JJA	2.4	3.1	4.1	5.1	6.4		-31	-15	-3	4	20
to	SON	2.4	3.0	3.5	4.6	5.8		-17	-4	4	11	24
50N,85W	Annual	2.3	3.0	3.5	4.4	5.8		-16	-3	3	7	15
1980 to 1999												
CNA	DJF	-4.0	-2.4	-0.8	0.8	3.0		-37	-6	7	20	84
	MAM	-4.1	-1.3	-1.1	0.6	2.8		-17	-3	8	25	41
	JJA	-1.8	-0.3	0.4	1.6	3.5		-34	-21	-12	15	39
	SON	-3.8	-1.3	-0.6	0.4	2.3		-37	-24	-16	0	24
	ANN	-3.2	-1.0	-0.5	0.6	2.6		-18	-8	2	5	21

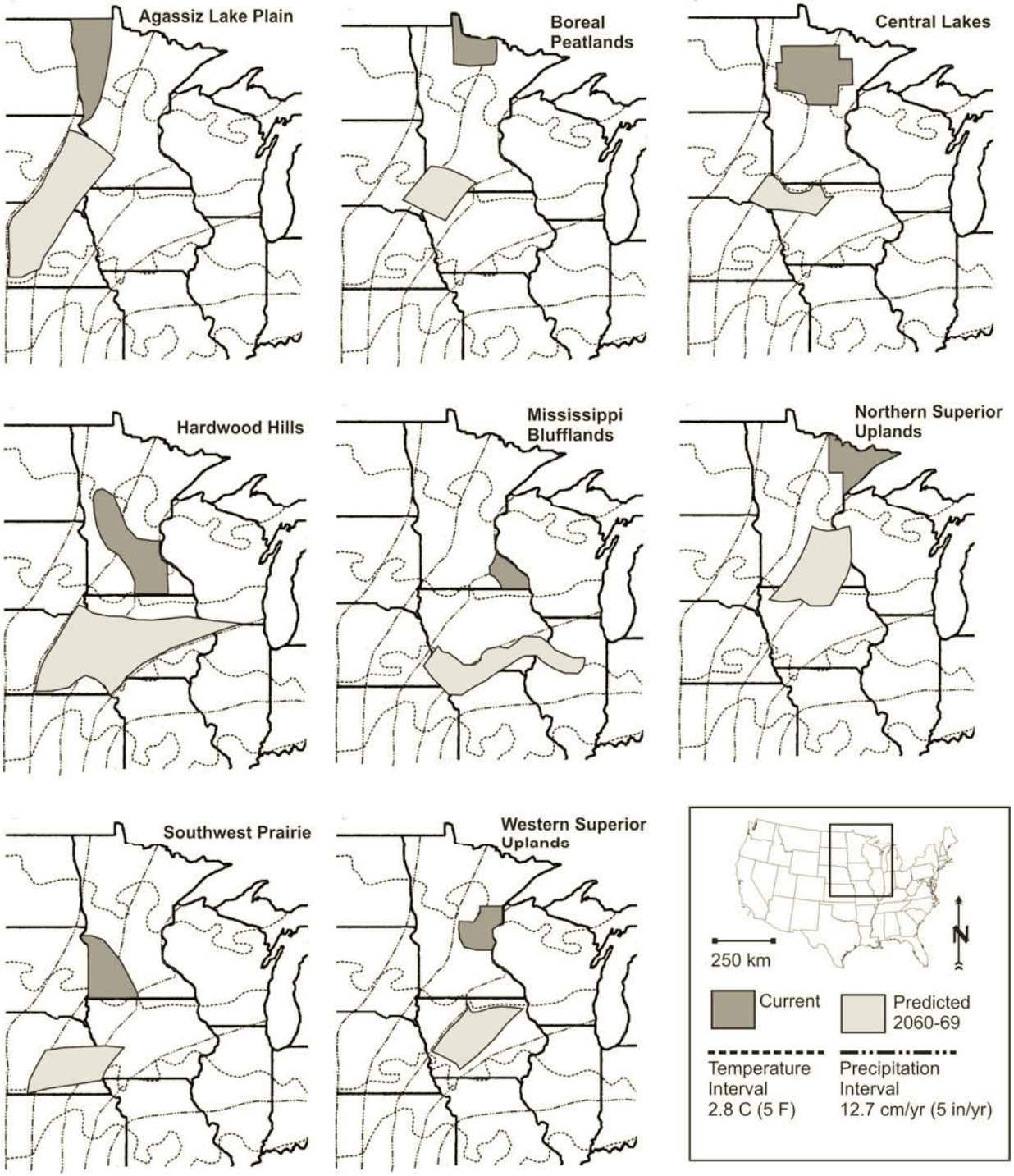
‘Projections’ of ***past*** conditions

- missed temperature by -4.1 to 3.5
- missed precipitation by -37% to +84%

‘Downscale’ for local detail …



Regional climate change adaptation strategies for biodiversity conservation in a midcontinental region of North America
2009 Susan Galatowitsch, Lee Frelich, Laura Phillips-Mao



Geographic Analogies:

Places where the current climate resembles the climate projected for the future.

2009 Susan Galatowitsch, Lee Frelich, Laura Phillips-Mao

The Nature Conservancy
Protecting nature. Preserving life.™

ClimateWizard

University of Washington
The University of Southern Mississippi

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Analysis Area	Time Period	Map Options	Measurement	Resources
◉ United States ○ Global United States	○ Past 50 Years ○ Mid Century (2050s) ◉ End Century (2080s)	○ Map of Average ◉ Map of Change	◉ Average Temperature ○ Precipitation Annual	Case Studies Documentation Data and Map Image Download ClimateWizard Custom Analysis Printer Friendly Version

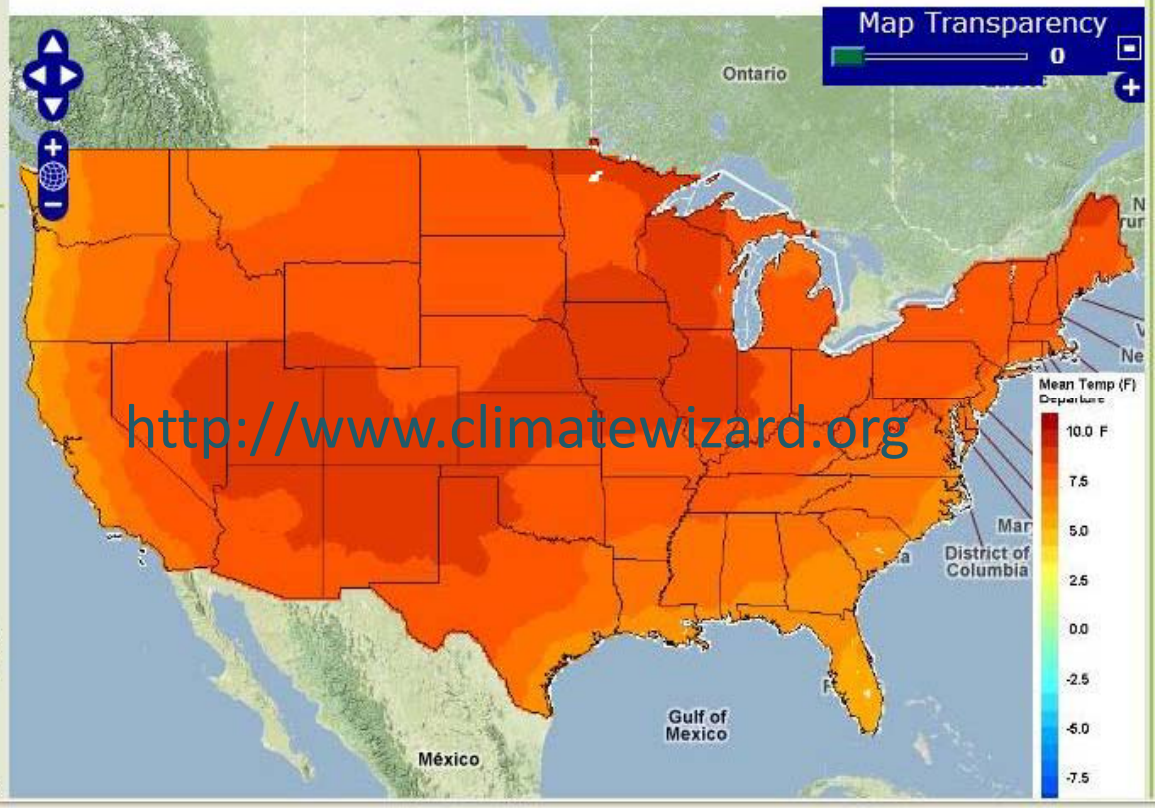
Future Climate Model

IPCC Fourth Assessment

Emission Scenario: High A2

General Circulation Model: Ensemble Average

Change in Annual Temperature by the 2080s
Model: Ensemble Average, SRES emission scenario: A2



50%: This map shows the temperature change projected by the middle model. That is, **half of the models project a greater amount of change, and half of the**

Climate Data for Climate Change Adaptation Analyses

Jim Zandlo
State Climatology Office – DNR Waters

DNR climate Change Adaptation Scoping Discussion
November 24, 2009

Climate Impacts Science Primer: How do scientists project future climates and their impact on resources in Washington State (WA) and the Pacific Northwest (PNW)?

1. Estimate future atmospheric greenhouse gas concentrations and other climate drivers.

Q1 - What do scientists have to know before they can project future climate?

2. Use global climate models (CMs) to project future climate at a global scale

3. Downscale CM results to project the future climate of WA and the PNW

See Climate Impacts Science Questions for answers to Q1-Q9

4. Use regional hydrology models to project future snow-pack, streamflow, and soil moisture

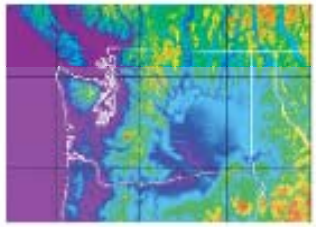
5. Use resource management models or empirical relationships to understand implications for WA and PNW resources

Q2 - How does a CM work?
Q3 - Why is there so much uncertainty in projected climate changes?
Q4 - Why can I believe climate change projections if it's impossible to forecast weather beyond two weeks?
Q5 - Which CM climate projections are most trusted? Which are less certain?

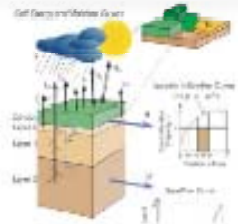
Q6 - What factors control WA and PNW climate?
Q7 - How do scientists "down-scale" CM results to a regio like WA?

climate change impacts on the water cycle?

Q9 - How do scientists project impacts on natural resources?



WA topography with typical GCM grid resolution (~150 miles)



VIC hydrology model

Salmon in Lake Washington

Prepared by Jennifer Kay, Joe Casola, Amy Snover, and the Climate Impacts Group (CIG) at the University of Washington for King County's October 27, 2005 Climate Change Conference. This and other conference materials are available at: http://www.cses.washington.edu/cig/outreach/workshops/kc2005.shtml

Presented by Stickel, Portland 2009

The Modeled Future

- What's needed for addressing adaptation issues?
  - summary of changes for some specific date or the trend over time relative to a base period.
  - time series used to emulate what's affected

- General Circulation Models (GCMs)
  - used for ***global climate*** modeling
  - complicated
  - time series of future climatic conditions

The Modeled Future

- General Circulation Models (GCMs)
  - Time series use
    - ‘raw’
    - Downscaled
      - Statistical
      - Dynamic (regional climate models)
  - Statistics use
    - Trends and differences
    - derived time series
      - Analogy (past observations that look like modeled future)
      - Stochastic (weather generator)

What ***is*** needed from the 'data' for adaptation studies?

- Summary of changes for some specific date or the trend over time relative to a base period.
  - e.g. 5°F warmer in 2050 than 1970-2000
  - e.g. a graph (time series) of ***relative*** changes.
- Time series used to emulate what's affected
  - annual, monthly, daily, even sub-daily available
  - GCM model 'data' generally has biases
  - Use in 'applied' model; e.g. fish survival

The Modeled Future

- Many General Circulation Models (GCMs) which are used for ***global climate*** modeling.
  - Many institutions have their own models
  - Many scenarios of the future conditions that we 'control'
  - Many starting points ('initial conditions') for calculations

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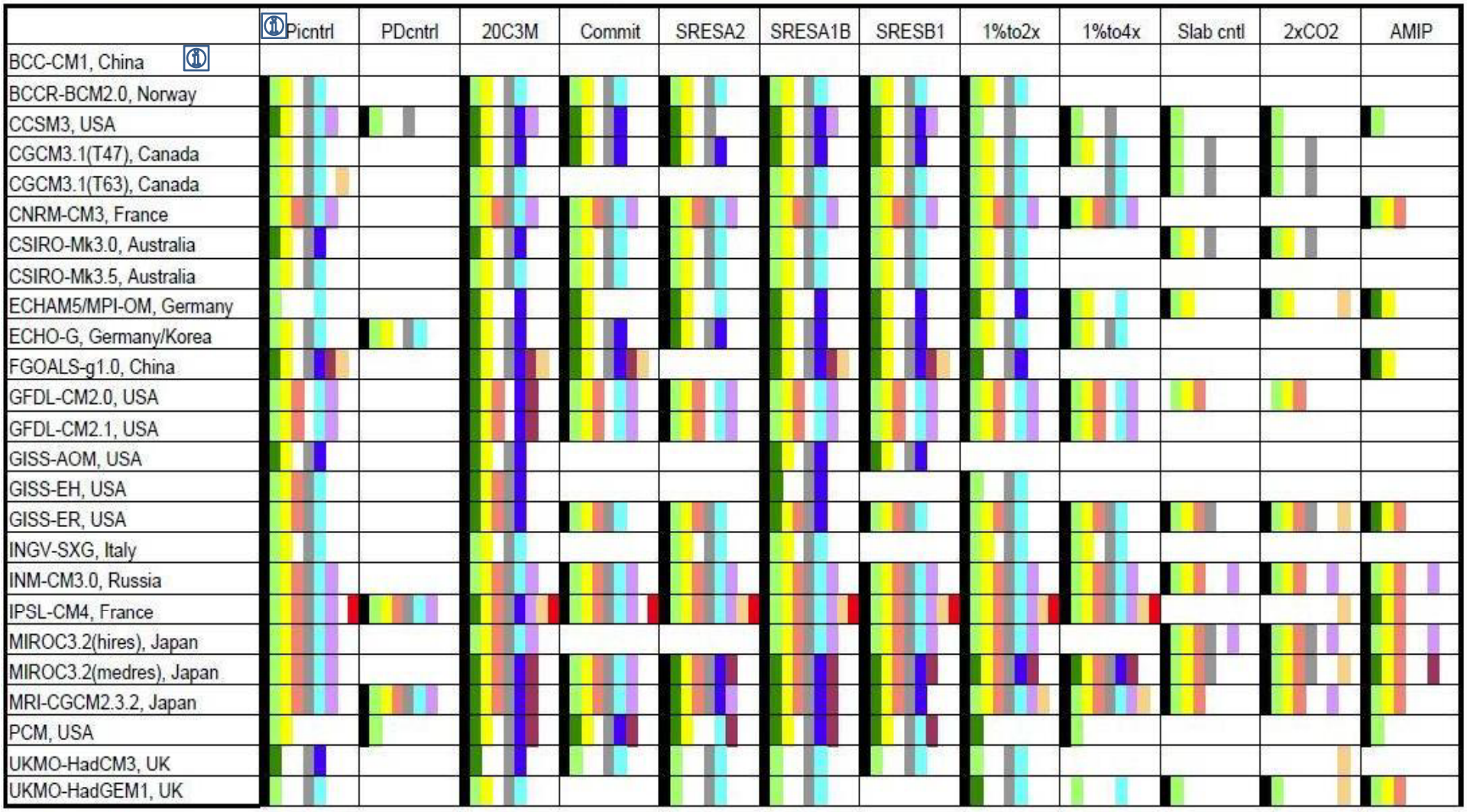
Adopted from: http://en.wikipedia.org/wiki/Special_Report_on_Emissions_Scenarios

Data Availability Summary (as of 27 February 2008)

shaded area indicates that at least some but not necessarily all fields are available for data type indicated

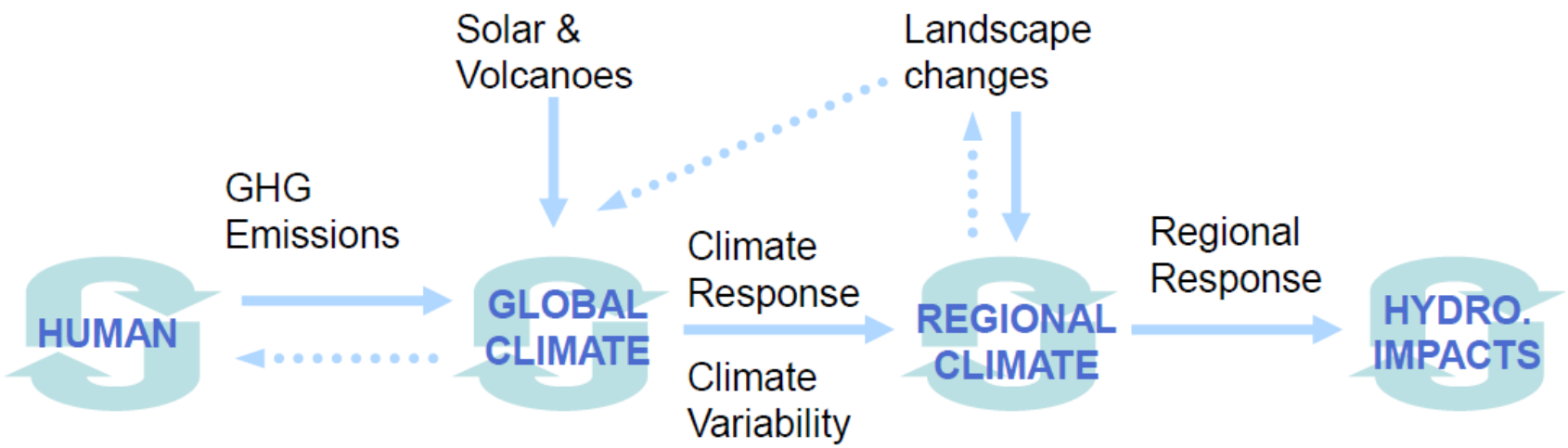
time-independent land surface
>1 1 monthly-mean atmosphere
daily-mean atmosphere
3-hourly atmosphere
time-independent ocean
>1 1 monthly-mean ocean
>1 1 Extreme Indices
Forcing
ISCCP Simulator



WCRP CMIP3 - http://www-pcmdi.llnl.gov/ipcc/about_ipcc.php

'World Climate Research Programme – Coupled Model Intercomparison Project'

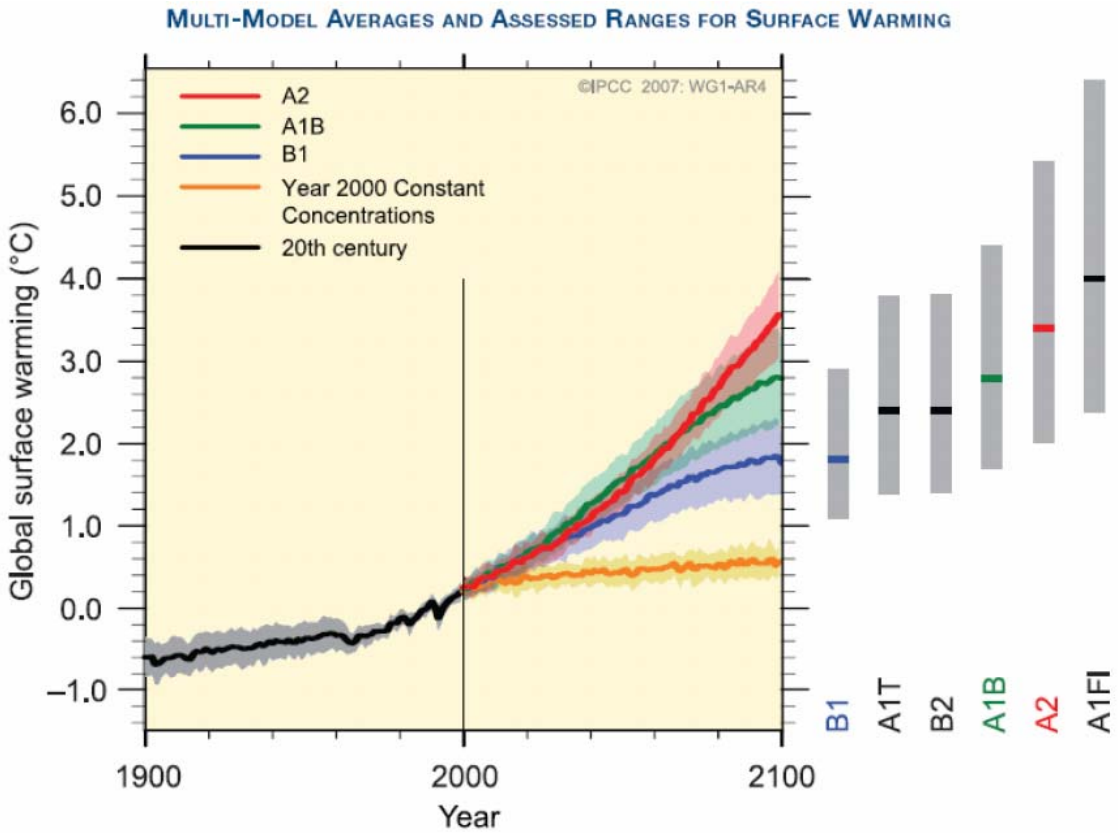
Chain of Uncertainty



Uncertainty is added in each layer of models and assumptions…

The Modeled Future: Uncertainty

- 'Que sera, sera' – things will change, we're just not sure how
- Model differences: unresolved science
- Intrinsic (initial conditions)

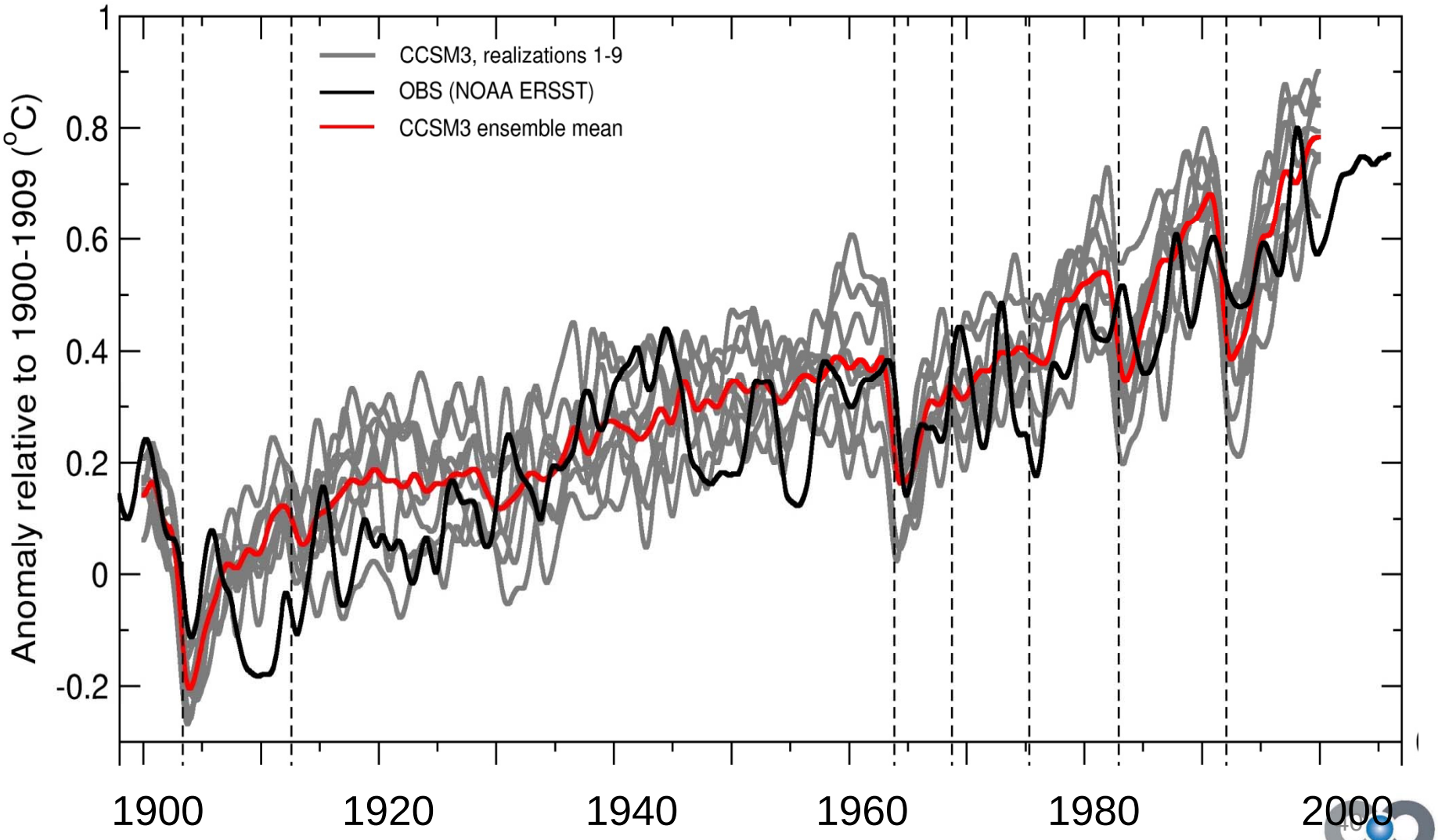


Presented by Ben Santer, Portland 2009

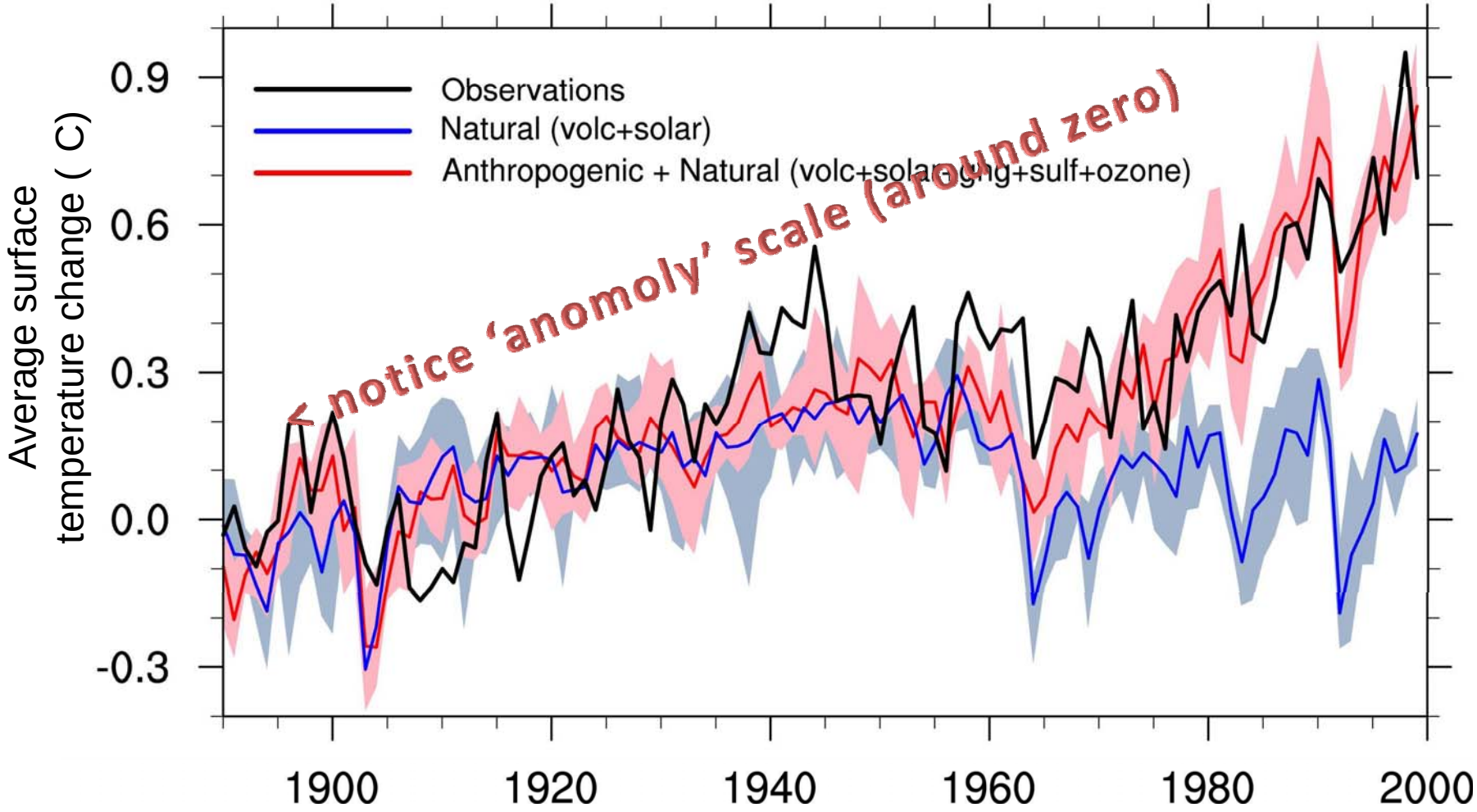
Example of initial condition uncertainty

Simulated and observed regional sea-surface temperatures

courtesy Ben Santer



Computer models can perform the “control experiment” that we can’t do in the real world

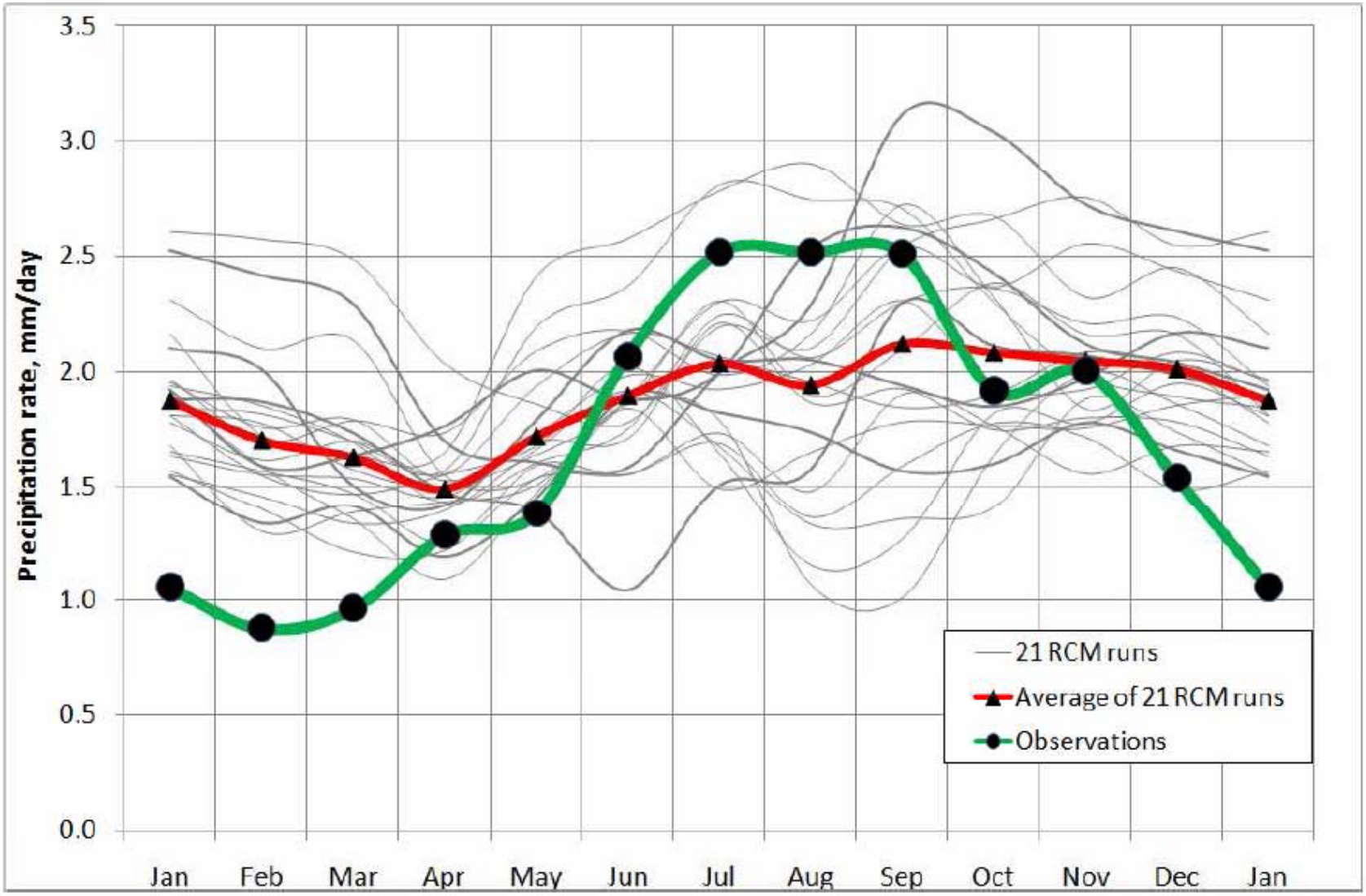


Meehl *et al*., *Journal of Climate* (2004) as presented by Ben Santer, Portland 2009

The Modeled Future (past)

- GCMs are judged by how well their calculations of the climate of some recent period (e.g. 1970-2000) compare to what was measured.
  - Trends: match well
  - Absolute values and (?) statistical distribution: ‘not so much’

Typical biases of precipitation



PowerPointPDF - A method of correction of regional climate model data for hydrological modelling, *Juris Sennikovs, Uldis Bethers*

What is Downscaling?

Something you do to a 20th-Century climate model simulation to reproduce the observed climate.

Will also give the projected regional climate change when applied to a future climate model simulation.

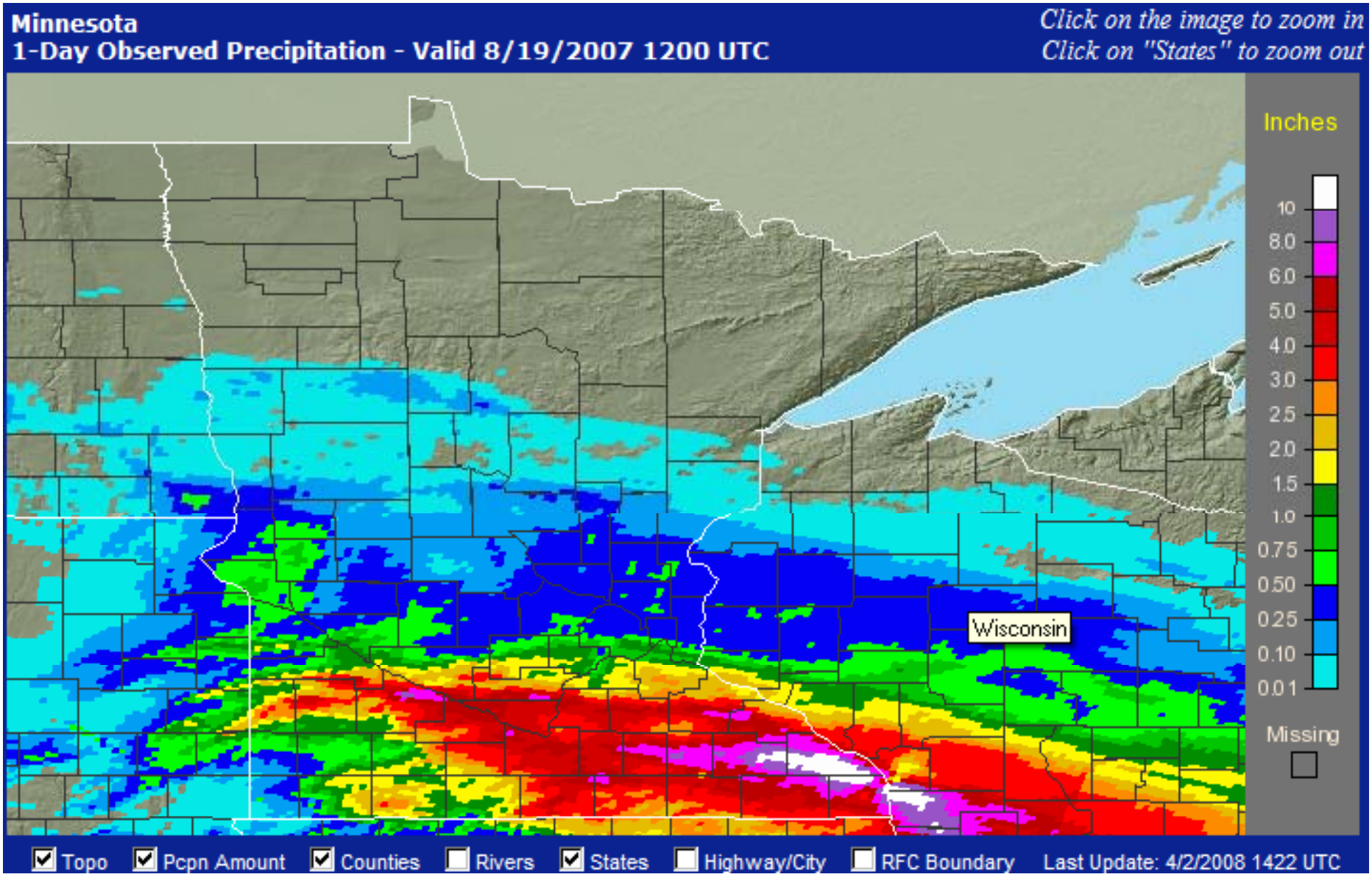
From Salathe, Portland 2009

An Example: hydrology models

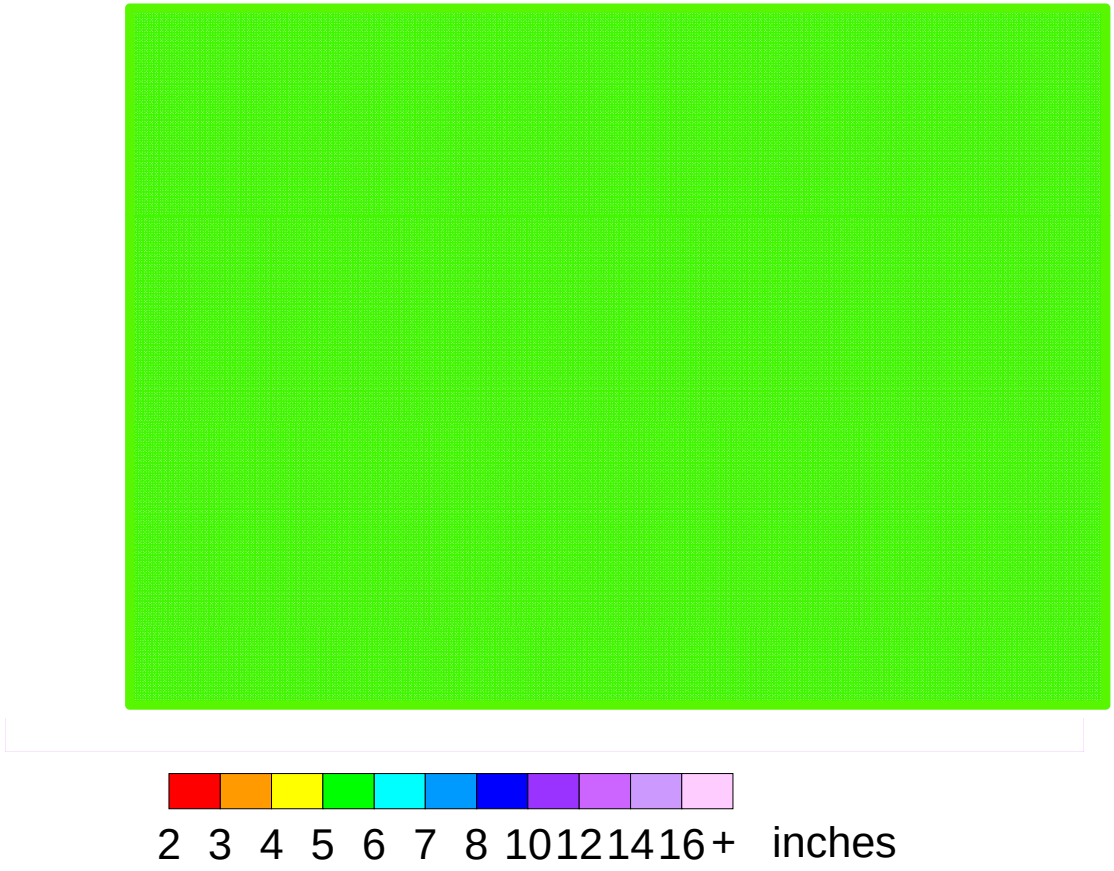
Need runoff (RO)

- Daily or even sub-daily required
  - Highly non-linear response
    - RO zero or very small unless a precip threshold is reached
    - Heavy RO only occurs for largest precip events
- GCM models
  - Precip is average over a large area. But, averages over large areas, of course, are always no bigger and generally much smaller than amounts that fell at any given point within the area.
  - Readily available 'downscaled' GCM data currently only on a monthly time scale (same sort of problem as with areal averages; i.e. what happened over a smaller slice of time such as a day?).

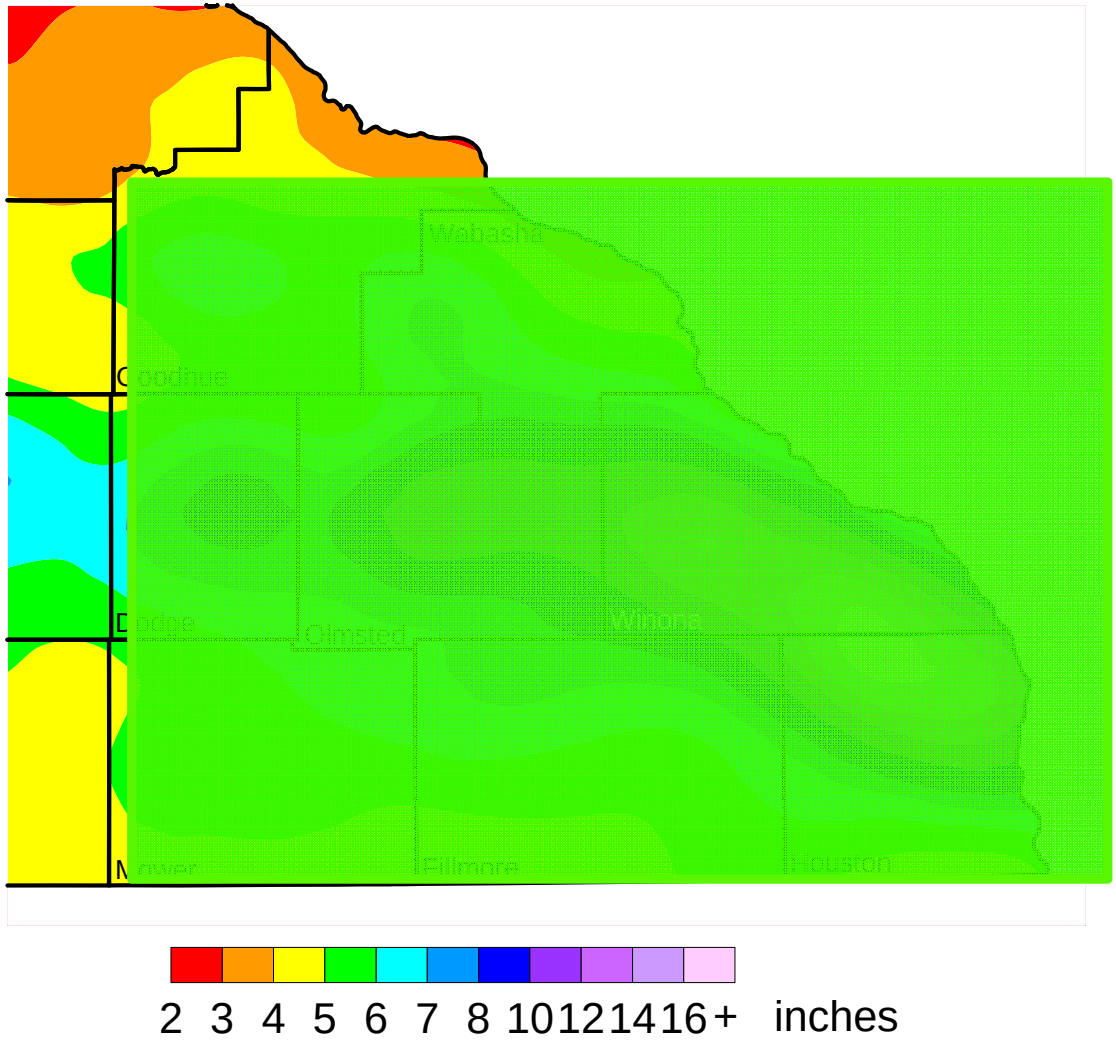
That is, the GCM estimates of future conditions cannot be used 'as is' by someone using long-standing existing hydrologic modeling techniques.


Minnesota
1-Day Observed Precipitation - Valid 8/19/2007 1200 UTC
Click on the image to zoom in
Click on "States" to zoom out
Inches
10
8.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.75
0.50
0.25
0.10
0.01
Missing
Wisconsin
Topo
Pcpn Amount
Counties
Rivers
States
Highway/City
RFC Boundary
Last Update: 4/2/2008 1422 UTC

In a 1°x2° GCM grid cell (thousands of square miles) a single value for precipitation is calculated.



Rainfall Totals for Southeastern Minnesota
August 18-20, 2007



In a 1°x2° GCM grid cell (thousands of square miles) a single value for precipitation is calculated.

An intense storm can have precipitation changes of as much as one inch per mile.

Rainfall Totals for Southeastern Minnesota
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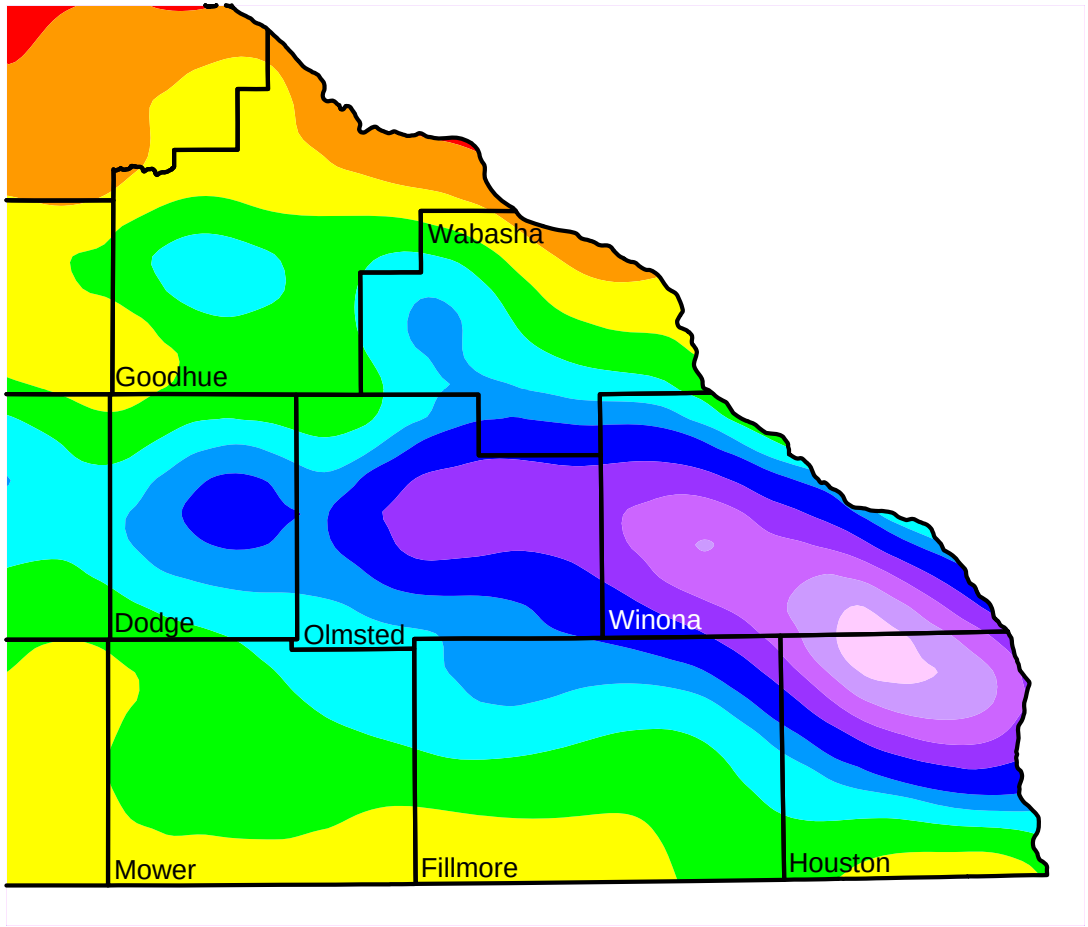


In a 1°x2° GCM grid cell (thousands of square miles) a single value for precipitation is calculated.

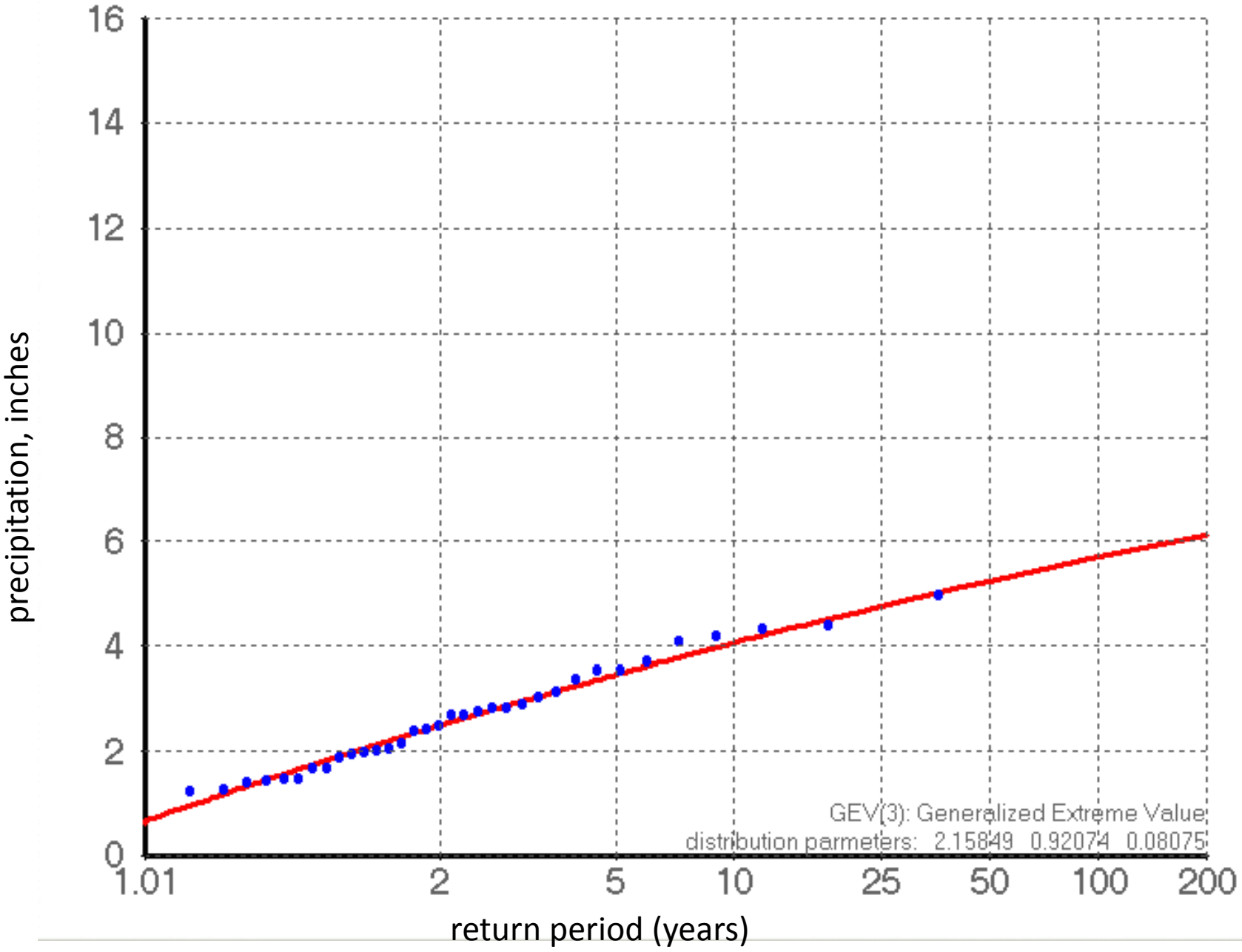
An intense storm can have precipitation changes of as much as one inch per mile.

6 inches of rain is readily handled by a ‘100 year design’ culvert but 16 inches will wash it away.

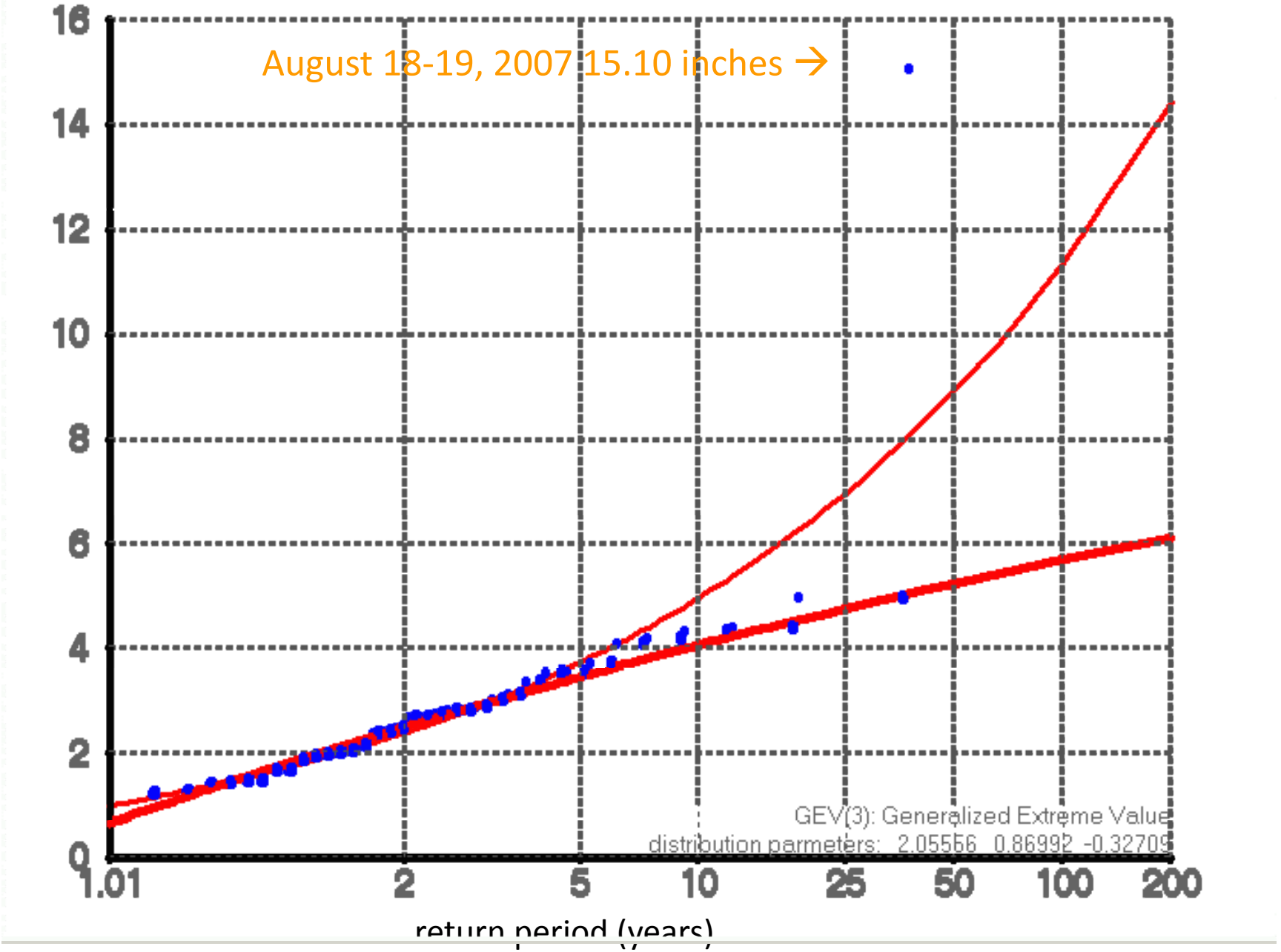
State Climatology Office - DNR Waters

created 10/26/07

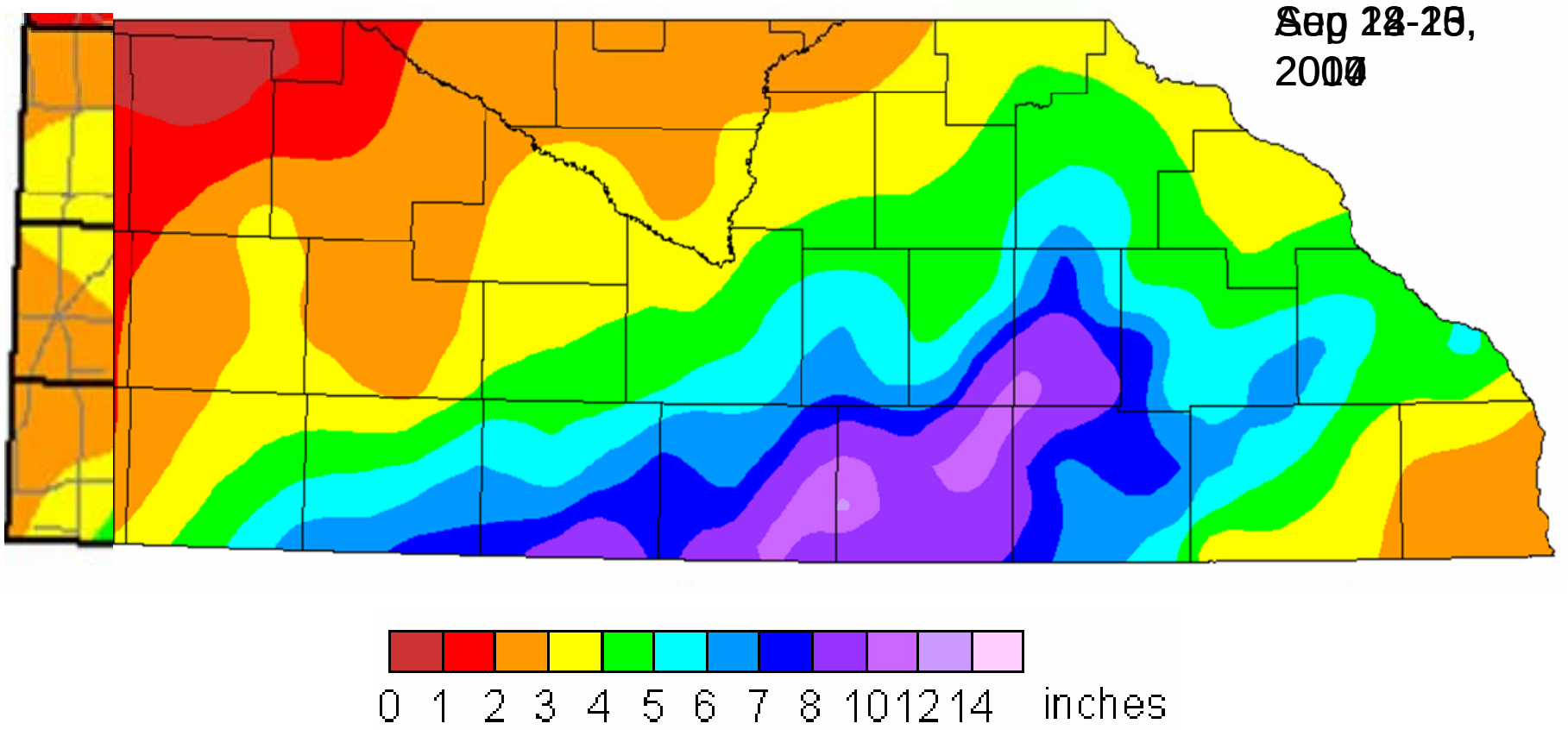
Hokah ann max daily PRCP vs. RP



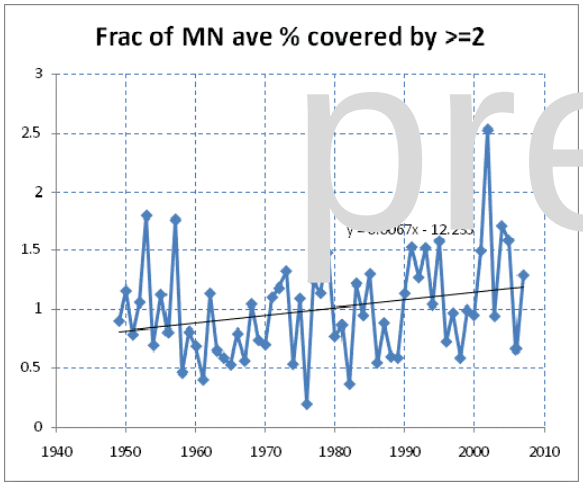
Hokah ann max daily PRCP vs. RP

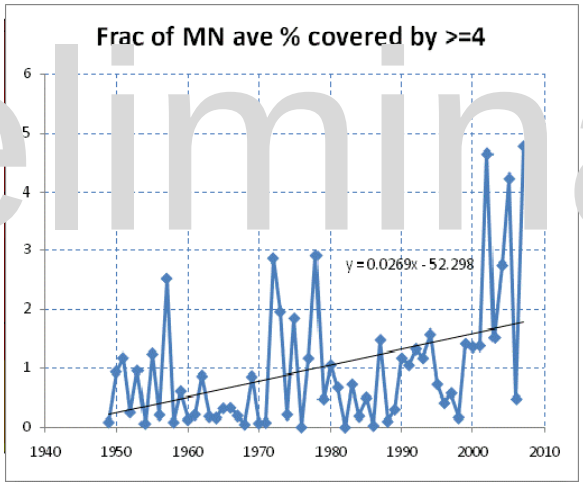


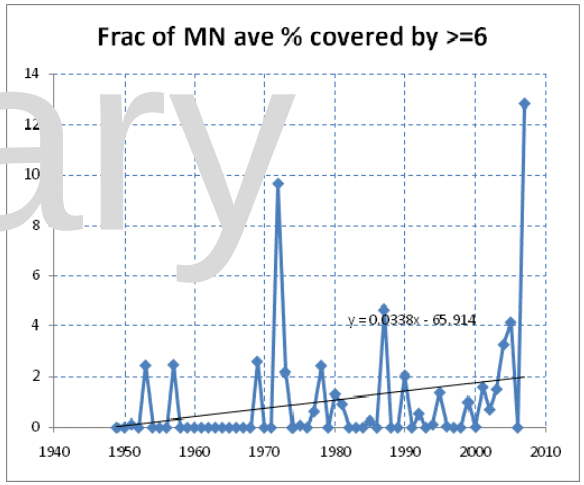
‘1000-yr (approx) events’
in Southern Minnesota in the last decade



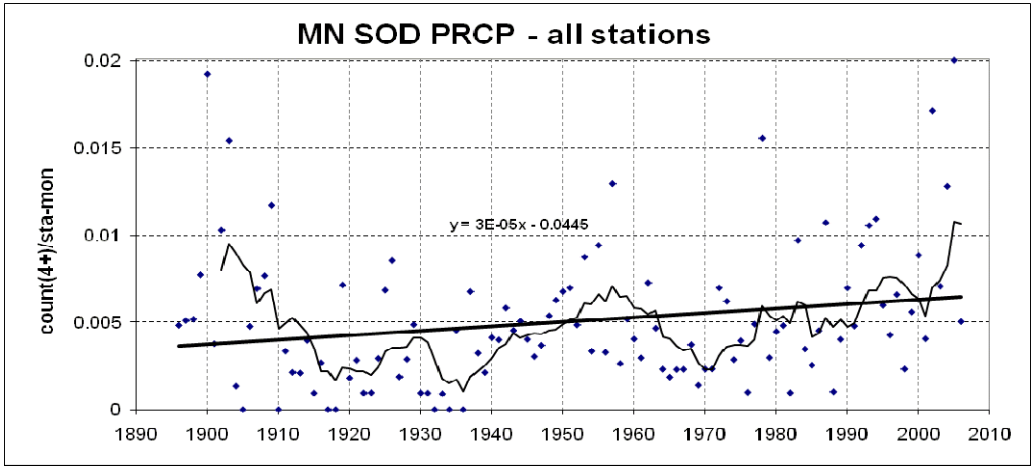
Changes in areas of Heavy Precipitation in Minnesota







- areas of heavy (multi-inch) rains per year are rising



- counts of heavy rains as a fraction of all rains are rising (but also note high count early in last century)

What is Downscaling?

Something you do to a 20th-Century climate model simulation to reproduce the observed climate.

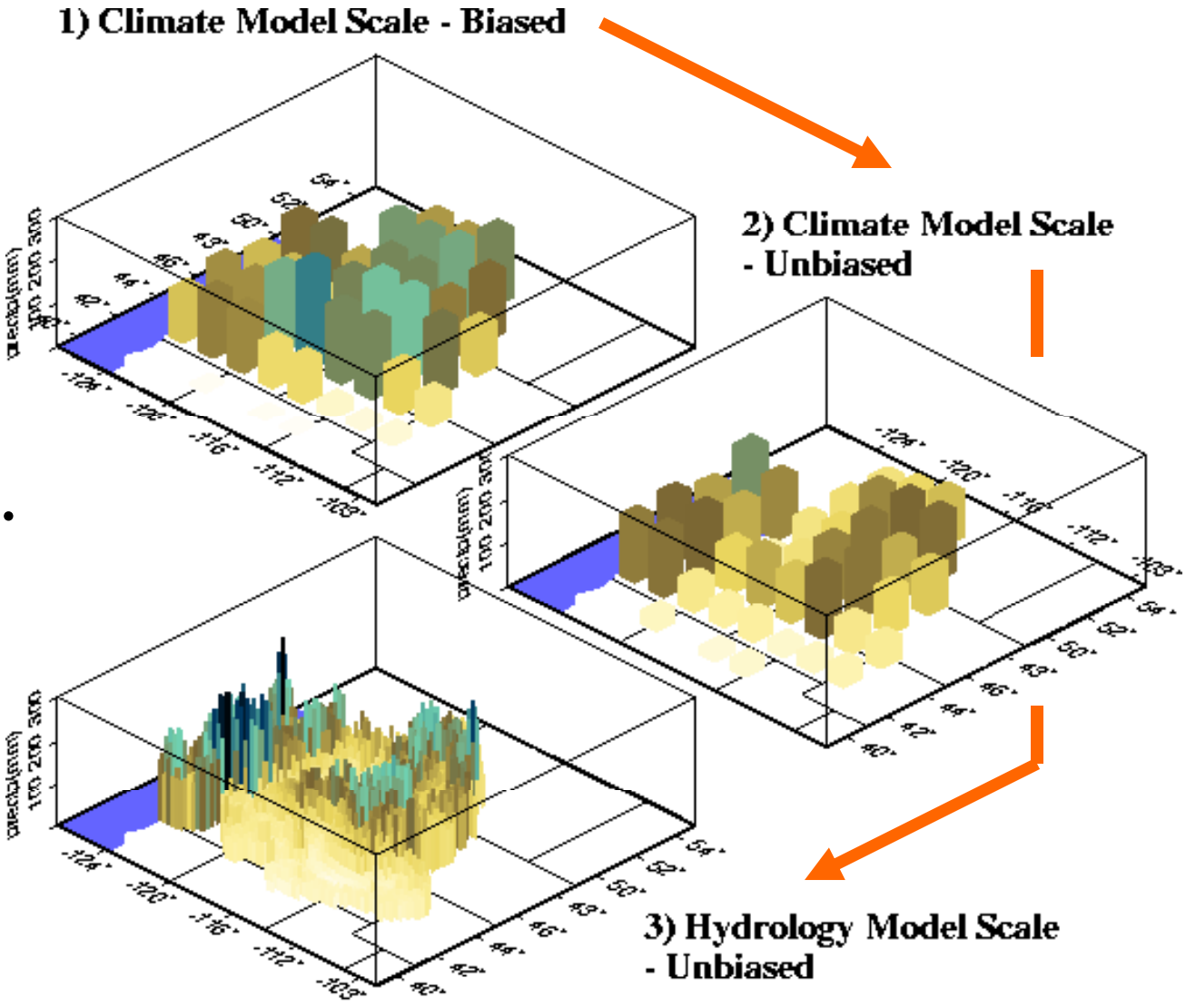
Will also give the projected regional climate change when applied to a future climate model simulation.

From Salathe, Portland 2009

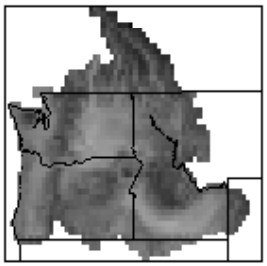
Challenge: Climate Model Forecast Use

bias-correcting…

then downscaling…

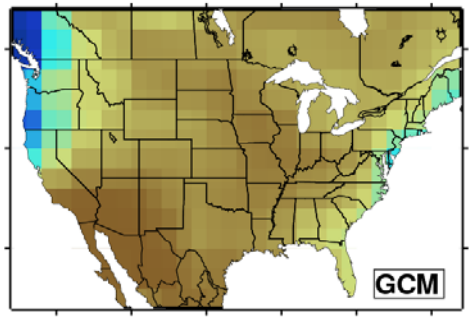


CRB domain, June precip

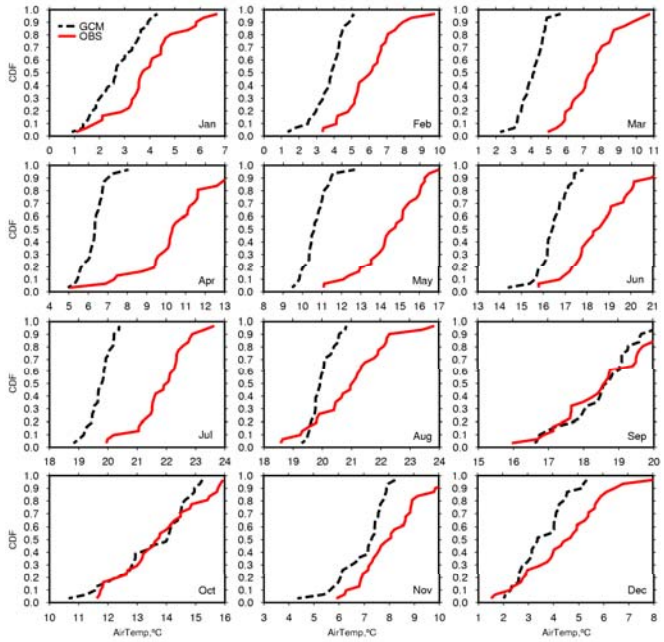


Experimental seasonal hydrologic forecasting for the Western U.S., Lettenmaier, 2004

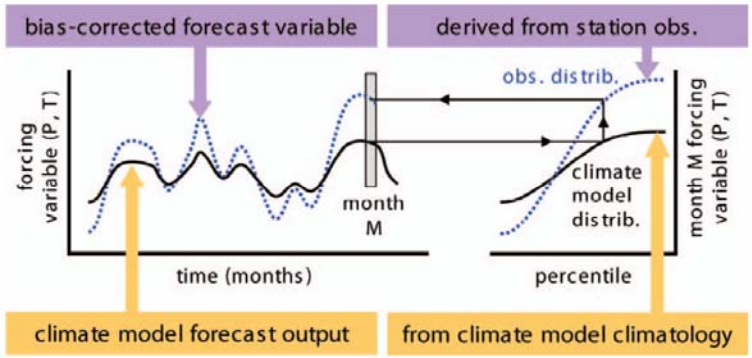
BCSD Method – "BC"



- At each grid cell for "training" period, develop monthly CDFs of P, T for
  - GCM
  - Observations (aggregated to GCM scale)
  - *Obs are from Maurer et al. [2002]*
- Use quantile mapping to ensure monthly statistics (at GCM scale) match
- Apply same quantile mapping to "projected" period

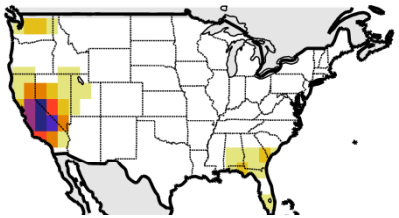


Wood et al., BAMS 2006



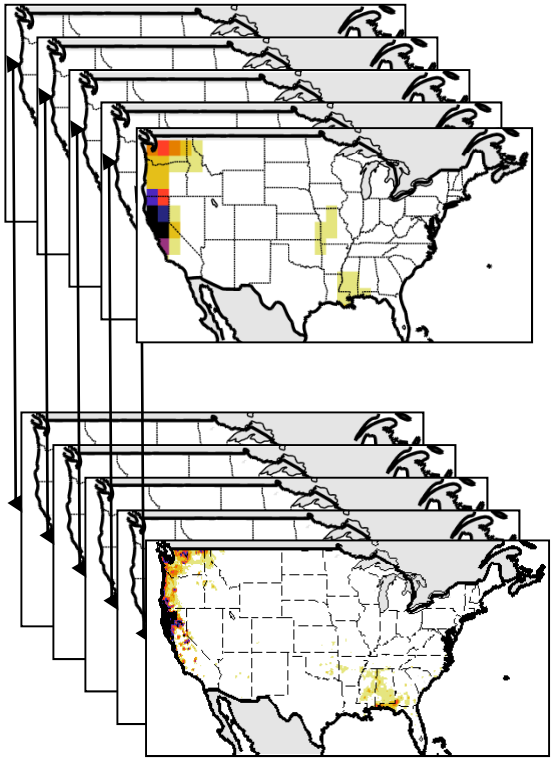
As presented by Maurer (Santa Clara U), Portland 2009

Constructed Analogues

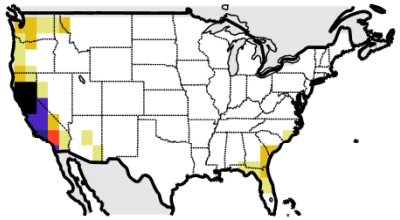


Given daily GCM anomaly

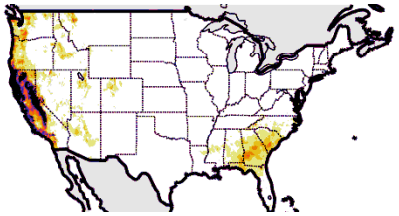
Library of previously observed anomaly patterns:



Coarse resolution analogue:



Analogue is linear combination of best 30 observed



Apply analogue to fine-resolution climatology

Climate Impacts Science Primer: How do scientists project future climates and their impact on resources in Washington State (WA) and the Pacific Northwest (PNW)?

1. Estimate future atmospheric greenhouse gas concentrations and other climate drivers.

Q1 - What do scientists have to know before they can project future climate?

2. Use global climate models (CMs) to project future climate at a global scale

3. Downscale CM results to project the future climate of WA and the PNW

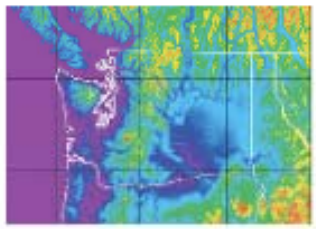
See Climate Impacts Science Questions for answers to Q1-Q9

4. Use regional hydrology models to project future snow-pack, streamflow, and soil moisture

5. Use resource management models or empirical relationships to understand implications for WA and PNW resources

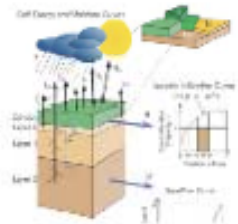
Q2 - How does a CM work?
Q3 - Why is there so much uncertainty in projected climate changes?
Q4 - Why can I believe climate change projections if it's impossible to forecast weather beyond two weeks?
Q5 - Which CM climate projections are most trusted? Which are less certain?

Q6 - What factors control WA and PNW climate?
Q7 - How do scientists "down-scale" CM results to a region like WA?



WA topography with typical GCM grid resolution (~150 miles)

Q8 – How do scientists project climate change impacts on the water cycle?



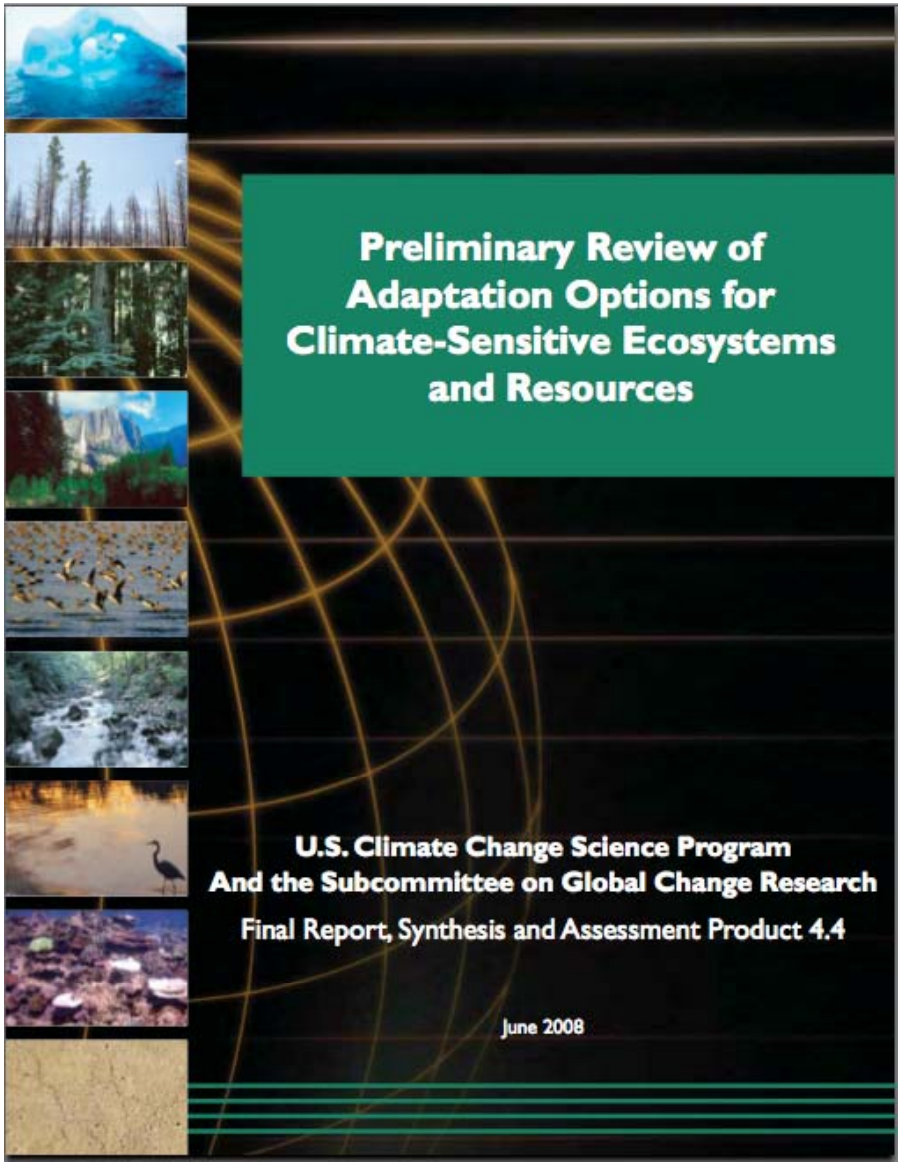
VIC hydrology model

Q9 - How do scientists project impacts on natural resources?

Salmon in Lake Washington

Prepared by Jennifer Kay, Joe Casola, Amy Snover, and the Climate Impacts Group (CIG) at the University of Washington for King County's October 27, 2005 Climate Change Conference. This and other conference materials are available at: http://www.cses.washington.edu/cig/outreach/workshops/kc2005.shtml

Presented by Stickel, Portland 2009



http://www.globalchange.gov/publications/reports/scientific-assessments/saps/306

Climate Change
Observed and Projected

Jim Zandlo
State Climatology Office - DNR – EcoWaters

MN Forest Resources Council Meeting
March 23, 2011

http://climate.umn.edu/doc/CC1103.ppt

Glossary - acronyms

- BC — Bias Correction
- CA — Constructed Analogues
- CDF — Cumulative Distribution Function
- CF — Climate and Forecast (metadata conventions)
- CMIP — Coupled Model Intercomparison Project
- ESG — Earth System Grid
- GCM — General Circulation Model, global climate model
- IPCC — Intergovernmental Panel on Climate Change
- NARCCAP — North America Regional Climate Change Assessment Project
- NCAR — National Center for Atmospheric Research
- NCDC — National Climatic Data Center
- netCDF — network Common Data Form (**ALL** GCM data in this format)
- PCDMI — Program for Climate Model Diagnosis and Intercomparison
- SD/SDS — Statistical Downscaling
- SRES — Special Report on Emissions Scenarios (IPCC)
  - » A/B: 'business-as usual' (growth)/'green', 1/2: 'one world'/'to each his own'
- WCRP — World Climate Research Program

Glossary

ensemble	for a given scenario, a collection of the output from more than one model or set of initial conditions
forcing	representation of physical environment of the system to be calculated; e.g. CO2 changes through time
scenario	a set of prescribed ‘forcings’ that will be used when calculating the climate; e.g. CO2 rising through time to double

GCM acronyms

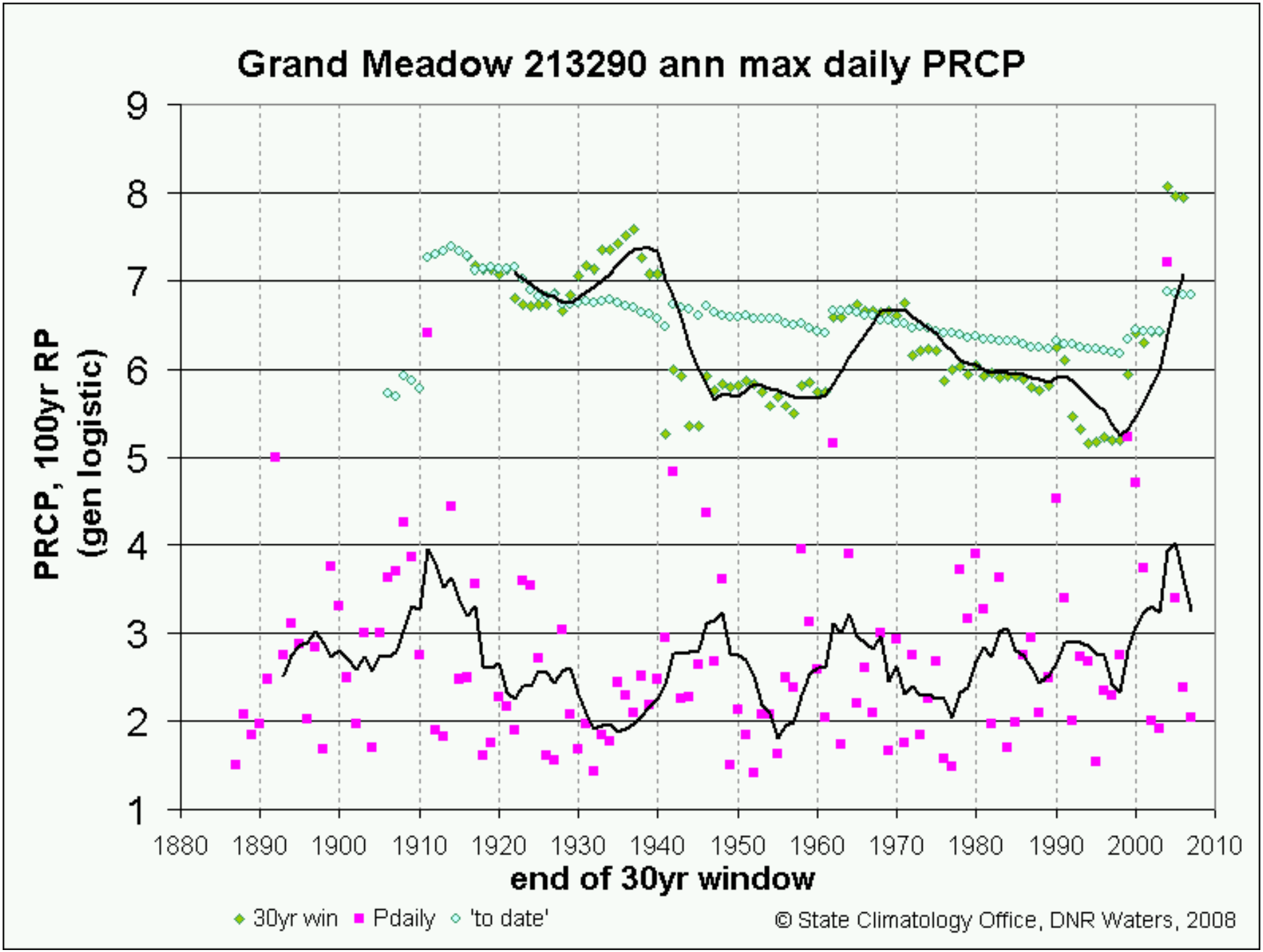
• BCC	Beijing Climate Center	China
• BCCR	Bjerknes Centre for Climate Research	Norway
• CCSM3	Community Climate System Model, NCAR	USA
• CGCM	Coupled General Circulation Model	Canada
• CNRM	Centre National de Recherches Météorologiques	France
• CSIRO	Commonwealth Sci. & Industrial Research Org.	Australia
• ECHAM	European Center (Forcasts) - Hamburg	Germany
• ECHO-G	ECHAM+HOPE-G (Hamburg Ocean Primitive Equation)	Germany / Korea
• FGOALS	???	China
• GFDL	Geophysical Fluid Dynamics Laboratory	USA
• GISS	Goddard Institute for Space Studies	USA
• INGV	Instituto Nazionale di Geofisica e Vulcanologia	Italy
• INM	Institute for Numerical Mathematics	Russia
• IPSL	Institut Pierre Simon Laplace	France
• MIROC	Model for Interdisciplinary Research on Climate	Japan
• MRI	Meteorological Research Institute	Japan
• PCM	Parallel Climate Model (NCAR)	USA
• UKMO	UK Meteorological Office (Hadley Center)	UK

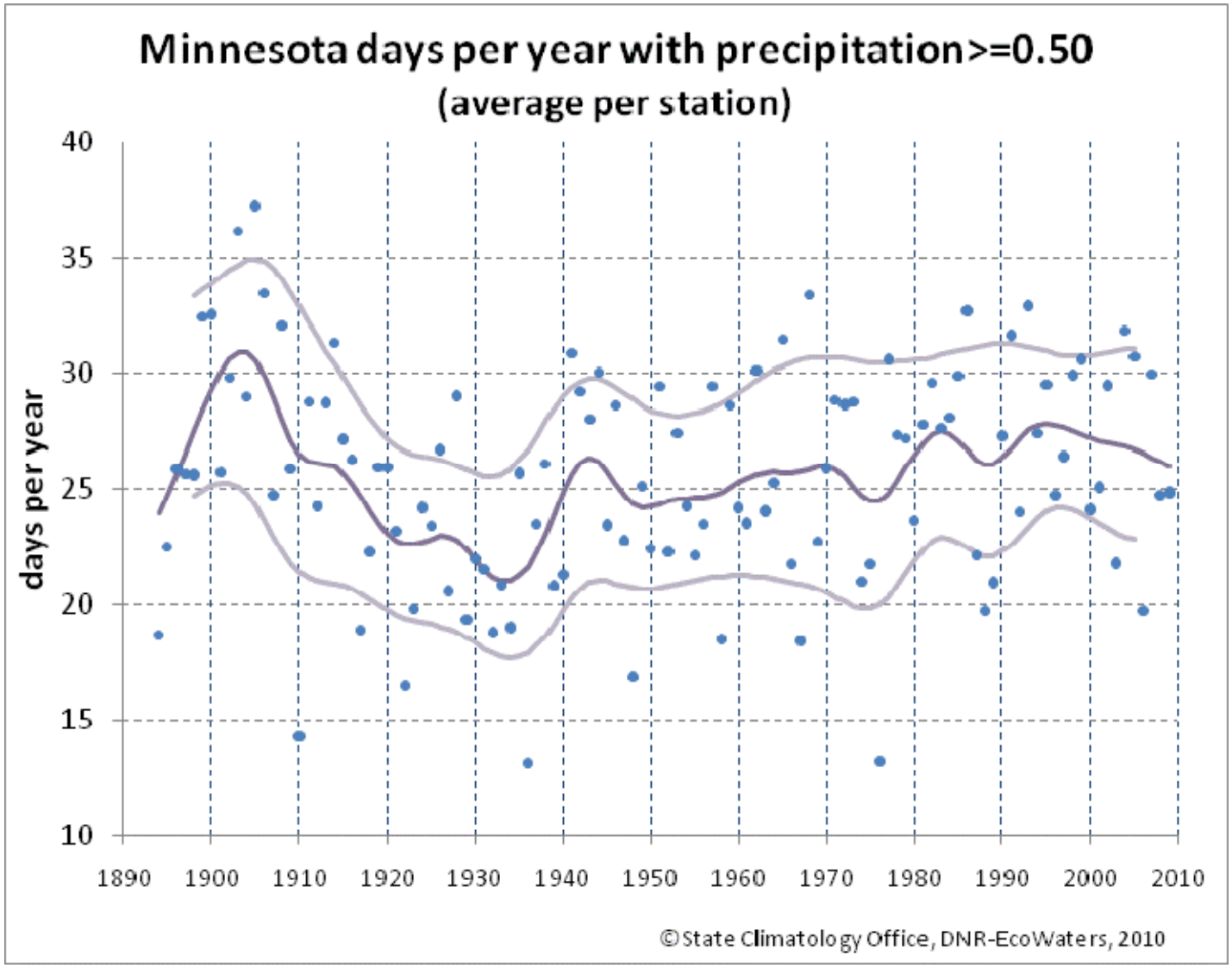
http://www-pcmdi.llnl.gov/ipcc/model_documentation/ipcc_model_documentation.php

GCM run scenarios

- Picntrl pre-industrial control
- PDcntrl present-day control
- 20C3M climate of the 20th century
- Commit committed climate change
- SRESA2 IPCC SRES A2
- SRESA1B IPCC SRES A1B
- SRESB1 IPCC SRES B1
- 1%to2x 1%/year until CO2 doubled
- 1%to4x 1%/year until CO2 quadrupled
- Slab cntl slab ocean control
- 2xCO2 2xCO2 equilibrium
- AMIP Atmospheric Model Intercomparison Project

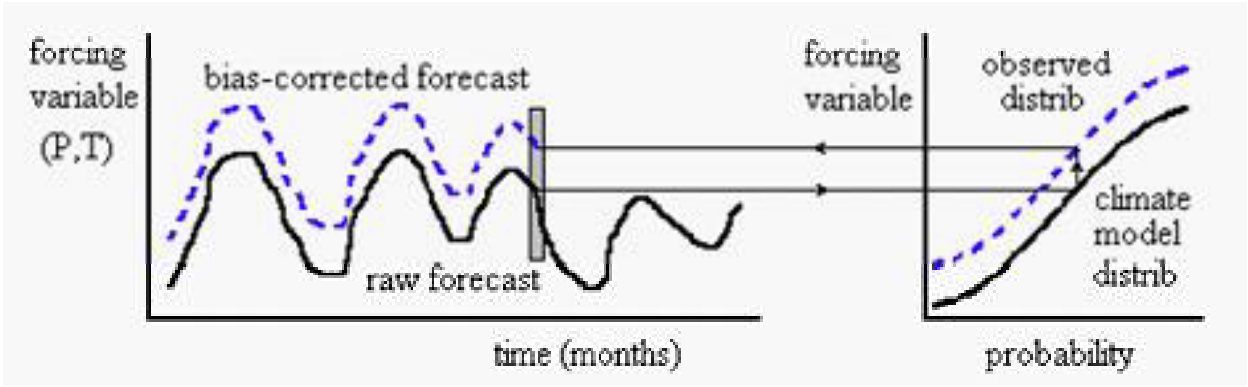
http://www-pcmdi.llnl.gov/ipcc/standard_output.html#Experiments

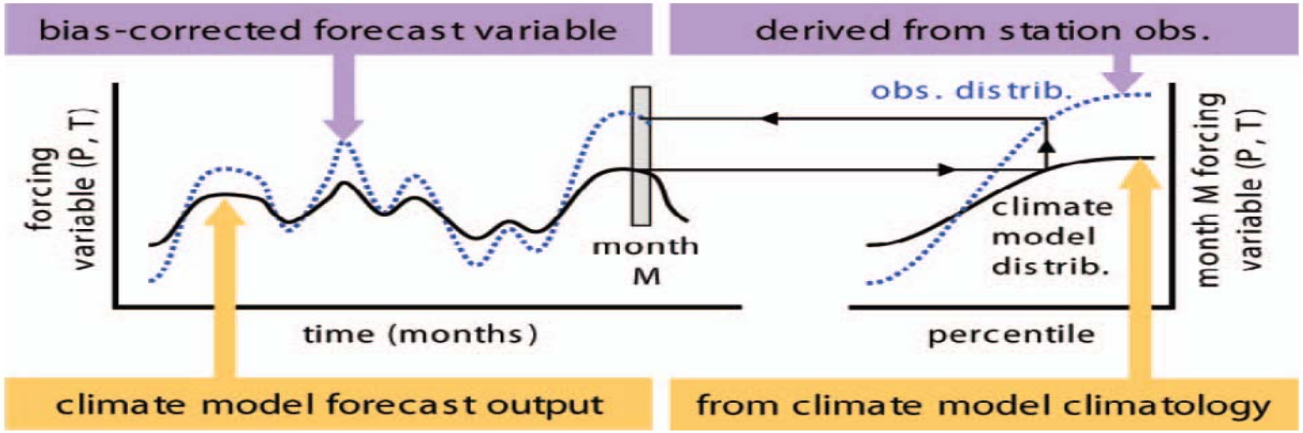

Grand Meadow 213290 ann max daily PRCP
PRCP, 100yr RP
(gen logistic)
9
8
7
6
5
4
3
2
1
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
end of 30yr window
30yr win
Pdaily
'to date'
© State Climatology Office, DNR Waters, 2008


Minnesota days per year with precipitation>=0.50
(average per station)
days per year
40
35
30
25
20
15
10
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
©State Climatology Office, DNR-EcoWaters, 2010

Bias Correction (BC)

Varying degree of bias geographically, between models, between scenarios, etc.





The Modeled Future

- Analogy
  - Constructed Analogues
    - Past geographical patterns used to ‘recognize’ GMC generated patterns
  - Local
    - e.g. ‘Climate Scenario at a Place’ [for Minnesota]
- Stochastic
  - Use ‘weather generator’ with observed distribution functions changed by the amount of change predicted by GCMs